Towards Defining the WRC Research Portfolio on Climate Change for 2008-2013

Report to the

Water Research Commission

by

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Definitions (as adopted by the UK Climate Impacts Programme)

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive capacity (resilience): how well a system can adjust to climatic changes, to moderate potential damages (by changing exposure or sensitivity), to cope with the consequences of impacts (by recovering or maintaining welfare/system function in the face of climatic change) and to profit from new opportunities (assuming climate change affects agents differentially).

Exposure: the extent to which a climate-sensitive sector is in contact with climate.

Mitigation: An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.

Sensitivity: the degree to which a system is affected by climate change.

Vulnerability: a measure of a system's susceptibility to climate change - a function of the system's exposure, sensitivity and adaptive capacity.

Acronyms

AIACC	Assessments of Impacts and Adaptations to Climate Change programme
ARC	Agricultural Research Council
BRDSEM	Berg River Dynamic Spatial Equilibrium Model
CC	Climate Change
CCAA	Climate Change Adaptation in Africa programme
CDM	Clean Development Mechanism
CSAG	Climate Systems Analysis Group
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environment Affairs and Tourism
DME	Department of Minerals and Energy
DNA	Designated National Authority for CDM projects
DoA	Department of Agriculture
DoT	Department of Transport
DST	Department of Science and Technology
DWAF	Department of Water Affairs and Forestry
ERC	Energy Research Centre
GCCC	Government Climate Change Committee
GCM	General Circulation model
GHG	Greenhouse Gas
HSRC	Human Sciences Research Council
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
IRM	Integrated Resources Management
LTMS	Long-term Mitigation Scenarios
NCCC	National Climate Change Committee
NCCRS	National Climate Change Response Strategy
NDMC	National Disaster Management Centre
NEMA	National Environmental Management Act
NEPAD	New Partnership for Africa Development
NGO	Non-governmental Organisation
NWRS	National Water Resource Strategy
RDM	Resource Directed Measures
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SEI	Stockholm Environment Institute
TNA	Technology Needs Assessment
UCT	University of Cape Town
UKCIP	United Kingdom Climate Impacts Programme
UKZN	University of KwaZulu-Natal
UNFCCC	United Nations Framework Convention on Climate Change
Wits	University of the Witwatersrand
WRC	Water Research Commission

Preface

In 2002 the South African water sector, through the Water Research Commission (WRC), initiated a comprehensive research programme on climate-change impacts on water resources with a view to gaining insight into the magnitude of the impacts and the consequential adaptation needs in the sector. Subsequently, first steps to incorporate research on vulnerability and adaptation into this programme were also taken. The largely successful impacts research leaned heavily on the outcomes of considerable prior investment by the WRC in water-related climate, atmosphere and ocean-atmosphere research, as well as hydrological modelling research, done over a period of more than 15 years.

Continuing with these efforts, the WRC compiled a comprehensive discussion paper detailing all current research efforts in South Africa that address climate change in relation to water, as well as the national policy environment within which such research is being carried out. The purpose of the paper was to promote alignment and eventual convergence of research investments in this area by all role players and, furthermore, to encourage the identification and exploitation of opportunities for cross-sectoral research partnerships. Complementing this discussion paper was a national workshop, held at the WRC, that provided a platform for dialogue and sharing among most role players. The excitement and robust debate engendered by this event was evidence of its timeliness and the need for more regular get-togethers on a topic that is critical to the future well-being of the country and its citizens.

The draft paper referred to above was reworked repeatedly to accommodate comments by stakeholders and workshop discussion, and is here presented, in its final form, for the information of all South Africans interested in climate change and water. Special thanks are due to the persons listed below, who either contributed to the document through written or verbal comments, and/or attended the workshop. Special thanks are due to Dr George Green who authored the draft paper and facilitated the whole process.

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1 Introduction

The evidence for global climate change, largely as a result of human activities that produce greenhouse-gas emissions, is overwhelming. There is rapidly growing consensus among global climate model projections regarding the nature and extent of the change. The main climate change consequences related to water resources are increases in temperature, shifts in precipitation patterns, an increase in the frequency of flooding and droughts, and, in coastal areas, sea-level rise.

While the temperature signal of climate change is clear, the precipitation signal is mostly still dominated by natural climate variability. In many countries, including South Africa, rainfall variability could very well remain dominated by natural, as opposed to anthropogenic, factors for the next one to two decades, especially at the river basin scale. With variability of rainfall further amplified in hydrological responses to rainfall, the small 'signal' and large 'noise' in projected hydro-climatic scenarios creates uncertainty and will present an added challenge to the planning of appropriate water-sector responses to climate change. The ability to distinguish adequately between signal (change) and noise (variability) at the earliest possible stage would be helpful in clarifying appropriate response targets and corresponding challenges, especially with regard to adaptation.

According to the Inter-Governmental Panel on Climate Change (IPCC), the momentum of climate change is already such that even the most stringent global mitigation efforts would not serve to avoid further impacts in the next few decades; this makes adaptation at national and local scales essential, particularly in addressing near-term and medium-term impacts. Reliance cannot be placed on adaptation only, however. If climate change were allowed to proceed unmitigated, it may eventually exceed the capacity of natural, managed and human systems to adapt. This suggests that national responses should comprise a portfolio or mix of strategies that include not only adaptation, but also mitigation, technological development (to enhance both adaptation and mitigation) and research (on climate science, climate impacts, adaptation and mitigation). The IPCC further suggests that such portfolios could combine policies with incentive-based approaches, and actions at all levels from the individual citizen through to national governments and international organisations. Adaptive capacity could, for example, be enhanced by introducing the consideration of climate change impacts and adaptive measures in development planning and infrastructure design and by giving greater priority to measures to reduce vulnerability in existing disaster risk reduction strategies.

In 2002 the South African water sector, through the Water Research Commission (WRC), initiated a comprehensive research programme on climate-change impacts on water resources with a view to gaining insight into the magnitude of the impacts and the consequential adaptation needs in the sector. Subsequently, first steps to incorporate research on vulnerability and adaptation into this programme were also taken. The largely successful impacts research leaned heavily on the outcomes of considerable prior investment by the WRC in water-related climate, atmosphere and ocean-atmosphere research, as well as hydrological modeling research, done over a period of more than 15 years.

The growth in awareness of global-change issues as a result of IPCC studies and reports has introduced a new and rapidly evolving focus for climate and atmosphere research in the past decade. This necessitates redefining climate-related, and particularly global climate change-related research thrusts and programmes that the WRC supports on behalf of the water sector. Perhaps the largest change is the need for such research to be integrated into a larger body of climate-change research nationally, which embraces a multi-sectoral, multi-level approach in order to deal with multiple stresses and enable the country to successfully face up to challenges that climate change is expected to pose over coming decades.

This document sets out the background against which the development of a climate-change research portfolio with a water-sector focus was initiated and pursued, with the assistance of a wide complement of stakeholders. Besides this important contextual information, research ideas contributed by stakeholders have been captured within a framework that defines the scope and content of R&D activities of potential concern to the South African water sector. Results of a prioritisation process initiated through a stakeholder workshop provide a departure point for the finalization of the recommended research portfolio by the Water Research Commission, once again in consultation with selected stakeholders. It is intended that this portfolio will provide direction for WRC funding in this area over the next 5-10 years. Terms of reference for key research projects in the portfolio will be developed with the help of expert panels, before being published as the first step in the process of soliciting research proposals. The ultimate aim of the exercise is to ensure that water-sector research funds are henceforth invested effectively in the interests of ensuring that South African society becomes more resilient and is better able to adapt successfully to the impacts of global change, largely brought about by enhanced climate variability and accelerated climate change.

2 The South African Government Context

2.1 South African Government Responses to Global Climate Change

Addressing climate change issues is high on the government agenda in South Africa, as indicated by the following government initiatives:

- ***Participation in the UNFCCC and Accession to the Kyoto Protocol.***

The Department of Environmental Affairs and Tourism (DEAT), as South Africa's focal point for environmental conventions, has taken the initiative in coordinating actions and ensuring compliance with international obligations related to climate change on behalf of the government. The government ratified the UNFCCC in August 1997 and acceded to the UNFCCC's Kyoto Protocol in July 2002. The UNFCCC required parties to prepare an initial national communication, a requirement with which South Africa complied in 2003. This national communication reported on national circumstances, including greenhouse gas inventories for 1990 and 1994, the country's vulnerability to climate change and its potential to adapt, systematic observations and research undertaken, education, training and public awareness programmes required, projections made, policies developed, measures taken, options for mitigation and adaptation and a preliminary national needs assessment.

Although South Africa has at this stage not yet committed itself to reporting on greenhouse gas emission reductions (as Annex 1 countries do), it is expected to, and will most likely have to make commitments in this regard, during post-Kyoto (i.e. after 2012). In preparation for that eventuality, the Department of Environmental Affairs and Tourism has commissioned a long term mitigation scenario (LTMS) project with a view to develop GHG emission reduction scenarios and to position South Africa for the post-Kyoto era.

- ***National and Government Committees on Climate Change.***

In order to assist the Department of Environmental Affairs and Tourism in its mandate regarding the UNFCCC, the National Committee on Climate Change (NCCC) was established to act as an advisory body to the Minister of Environmental Affairs and Tourism. Representatives from relevant government departments, as well as representatives from business and industry, mining, labour, community based organisations and non-governmental organisations constitute the NCCC. The NCCC, for example, assisted DEAT in obtaining detailed reports on South African Country Studies relating to climate change, compiled on a sectoral basis.

More recently it was deemed advisable to establish a Government Committee on Climate Change (GCCC), to allow representatives of government to caucus internally and present a united front.

2.2 Government Strategies for Addressing Climate Change

The planning of a portfolio of strategies and activities is taking shape under the leadership of government departments such as DEAT, the Department of Science and Technology (DST), the Department of Minerals and Energy (DME) and the Department of Agriculture (DoA), with input from experts and researchers in academia and science councils.

2.2.1 National Climate Change Response Strategy

Using the results of the SA Country Studies, together with information from the IPCC Third Assessment Report, DEAT developed a national climate change response strategy (NCCRS), published in 2005. Each government department is expected to develop their own climate change response sector strategies in line with the NCCRS.

Key issues contained in the NCCRS

Supporting national and sustainable development
South Africa views climate change response as offering a specific opportunity for achieving the sustainable development objectives of those national policies and legislation that are concerned with both development and environment issues. At the same time, international action on climate change is viewed as a significant vehicle for redressing the historic, inequitable and unsustainable north/south divide with regard to the world's economy and prosperity.

Adapting to climate change
South Africa, being vulnerable to climate change impacts, will need to put adaptation measures in place. The South African Country Studies Programme identified the health sector, maize production, plant and animal biodiversity, water resources, and rangelands as areas of highest vulnerability to climate change; these need to be targeted for special assistance in developing adaptation measures. With regard to vital industries, the mining and energy sectors are particularly vulnerable to climate change mitigation. Further, the South African economy is vulnerable to the possible response measures implemented by developed (Annex 1) countries, being highly dependent on income generated from the production, processing, export and consumption of coal. This vulnerability extends across virtually all facets of the mining and energy sectors.

Developing a sustainable energy programme
South Africa, as a non-Annex I country, is not required to reduce its emissions of greenhouse gases. However, the South African economy is highly dependent on fossil fuels and the country can be judged to be a significant emitter due to the relatively high emissions per capita (one the world's top 15 most energy intensive economies). Benefits could be derived from adopting a future strategy that is designed to move the economy towards a cleaner development path, particularly with regard to accessing investment through the Clean Development Mechanism (CDM) of the Kyoto Protocol (see Section 2.4.4 under DME for more detail), technology transfer and donor funding opportunities. In addition, a DME white paper on renewable energy and clean energy development, together with an energy efficiency programme, supports diversification towards a less carbon intensive energy economy.

Meeting international obligations

South Africa, as a signatory to the UNFCCC, has to fulfil certain obligations, including actions to:

- Prepare and periodically update a national inventory of greenhouse gas emissions and sinks.
- Formulate and implement national and, where appropriate, regional programmes to mitigate climate change and facilitate adequate adaptation to climate change.
- Promote and cooperate in the development, application and diffusion of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases.
- Promote sustainable management, and promote and cooperate in the conservation and enhancement of sinks and reservoirs of all greenhouse gases.
- Cooperate in preparing for adaptation to the impacts of climate change.
- Take climate change considerations into account in the relevant social, economic and environmental policies and actions with a view to minimising adverse effects on the economy, on public health and on the quality of the environment.
- Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate uncertainties.
- Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change.
- Promote and cooperate in education, training and public awareness related to climate change.

The integration of climate change response in government

Although DEAT has been designated as the lead agency for climate change response in South Africa, it is recognised that climate-change response is a cross-cutting issue requiring that all government departments be involved and work together in a coordinated manner. Unfortunately, general awareness within government of the likely impacts of climate change has been somewhat limited in some departments, while in other departments climate change has not been seen as a priority and may even have been regarded as working against national development priorities, especially with the huge backlog in service delivery commanding the top priority. This requires that climate change be addressed in ways that promote achievement of service delivery objectives, i.e. through so-called “win-win” or “no regrets” measures.

Research development and demonstration

Technological change holds one of the keys to meeting long-term climate change challenges. Climate change research needs to be properly coordinated and the benefits optimised to meet the needs of policy-makers in South and southern Africa. Attention needs to be focussed on projects that will assist with mitigation of, and adaptation to, climate change and address specific areas of vulnerability. Further, development and demonstration projects are required to show the advantages and acceptability of a variety of technologies related to climate change.

Inventories of greenhouse gases and air pollutants
There is a need to put in place a national ambient air quality monitoring network and information handling system in order to obtain an integrated database for purposes of air quality management and greenhouse gas inventories.

Accessing and managing financial resources for climate change
An effective programme for climate change response will require that South Africa has access to public sector funding and funding from government related institutions, such as the Development Bank of South Africa. Further, as a developing country, South Africa can access assistance from developed country partners to meet its obligations under the UNFCCC and, further, participate in the global mitigation of climate change. This requires a framework to access and manage the climate change financial resources on offer as donor funding.

Key strategies and actions in the NCCRS for addressing above key issues

National objectives and sustainable development *(The aim is to create a synergy between national government objectives, sustainable development and climate change).*

- Develop indicators and criteria which denote whether particularly development pathways lead to sustainability; ensure that these indicators/criteria are consistent with indicators and criteria to be used by the designated national authority (DNA) for CDM projects.

Institutional arrangements (The aim is to e*nable the relevant national government departments to address climate change issues in South Africa).*

- Ensure that the relevant national government directorates and sub-directorates have the capacity to carry out their assigned functions regarding climate change response, including the CDM.
- Establish procedures for CDM projects.

Adaptation *(The aim is to offset South Africa's vulnerability to climate change).*

- Extension of health protection and health promotion measures.
- Water resource management and contingency planning.
- Adaptation of rangeland practices.
- Adaptation in agriculture.
- Changes in forestry practices.
- Protecting plant biodiversity.
- Protection of animal biodiversity.
- Protecting marine biodiversity.
- Formulate actions that will offset the economic vulnerability of South Africa to climate change response measures.

Mitigation *(The aim is to create a national greenhouse gas mitigation plan that furthers the process of sustainable development in South Africa in the light of CDM, technology transfer, donor funding and capacity building opportunities).*

- Harness efforts of all stakeholders to achieve the objectives of the Government's White Paper on Renewable Energy (2003) and the Energy Efficiency Strategy, promoting a sustainable development path through coordinated government policy.

- Initiate the Government's joint implementation strategy for the control of exhaust emissions from road-going vehicles.
- Implement a transport sector mitigation programme through the National Department of Transport, in conjunction with the Government's energy efficiency strategy (2003) and the joint implementation strategy for the control of exhaust emissions from road-going vehicles.
- Develop and implement an appropriate coal-mining sector mitigation programme through the Department of Minerals and Energy and the mining industry.
- Implement sustainable industrial development through coordinated policies, strategies and incentives through the Department of Trade and Industry and the various industry sectors.
- Reduce greenhouse gas emissions in the agricultural sector through the National Department of Agriculture.
- Facilitate the establishment and extension of forest schemes through the Department of Water Affairs and Forestry and the forestry industry.
- Optimise waste management practices to minimise the emissions of greenhouse gases and develop a government position, through all relevant departments and all spheres of government and industry, to implement a waste sector mitigation programme.

International concerns *(The aim is to optimise South Africa's potential to benefit from climate change mitigation by suitable international response and positioning).*
- Maintain an appropriate attendance at UNFCCC and related meetings.

Cross-cutting issues within government *(The aim is to ensure that government departments in all spheres work together on a cooperative basis in dealing with climate change).*
- Use the Government Committee for Climate Change to consolidate the government position.

Legislation *(The aim is to ensure that South African environmental law provides for climate change issues).*
- Use the ongoing law reform process to ensure that climate change issues are provided for in South African legislation.

Education, training, awareness and capacity building *(The aim is to improve the level of education, training and awareness regarding climate change in South Africa and capacitate the government and other sectors to deal with climate change issues effectively to the benefit of the country).*
- Accelerate the process of relevant education, training, awareness and capacity building in South Africa to speed up the implementation of climate change response.

Research, development and demonstration *(The aim is to ensure that there is an effective and integrated programme of climate change research, development and demonstration in South Africa).*
- Set up a database of climate change related research, development and demonstration projects and integrate the research, development and demonstration programme for South and Southern Africa.

Air quality management *(The aim is to Identify and put in place an information handling system that incorporates greenhouse gas data).*

- Introduce greenhouse gas emissions into air quality legislation and put in place a national information handling system that incorporates greenhouse gas data alongside air pollution data.

Accessing and managing financial resources for climate change *(The aim is to ensure that South Africa gets the best possible access to available climate change funding).*

- Ensure that an investment friendly climate is developed and maintained to attract developed country partners to invest in climate change related projects in South Africa.
- Coordinate climate change donor funds that are procured for South Africa.
- Involve the public sector and financing institutions linked to government, such as the Industrial Development Corporation and the Development Bank of South Africa.

2.2.2 Other DEAT Strategic Initiatives

As an extension of the National Climate Change Response Strategy, DEAT has initiated the development of a **National Long-term Mitigation Scenarios (LTMS)** project, being undertaken by UCT's Energy Research Centre on behalf of DEAT. This is currently still work in progress.

2.2.3 Department of Science and Technology (DST) Initiatives

2.2.3.1 South Africa's Climate Change Technology Needs Assessment Report

The National Climate Change Committee (NCCC) mandated DST to lead a Technology Needs Assessment (TNA) in relation to climate change. The resulting report is a resource document from which appropriate material is to be extracted for the development of an official technology needs assessment that South Africa will be submitting to the UNFCCC. The purpose of the resource document is to fully inform all the South African stakeholders of the technology needs in relation to climate change that have been identified in the first phase of the TNA process.

The TNA focuses on the most important technologies that can be appropriately transferred to South Africa from developed counties. These were identified by applying ten different measures (representing relevance to climate change, alignment with national strategies, sustainability, market potential and capacity development) in the prioritisation of technologies, after having classified them into three groups: adaptation, mitigation and cross-cutting issues.

The assessment suggests that the most important technological interventions should focus on adaptation linked with achieving sustainable development goals, such as water and sanitation, food security and health. Five of the top six options are adaptation options. Nevertheless, locally, mitigation is shown to be as important as adaptation (of the 15 top priority options, six are adaptation and nine are mitigation options). The need to use an economic approach to find and to implement the best mitigation options is clear and it seems that the provision of economic incentives will be an important tool in a rapidly developing country such as South Africa. All sectors need to be involved in mitigation, e.g.: the energy sector (energy efficiency and solar power), waste

management, agriculture (reduced tillage), land management (control of fire), industry (capture of flare gas) and public transport.

It is to be expected that many of the technological options that support either mitigation or adaptation in and across various sectors will have either water resource or water use implications, which would require water-sector participation in the evaluation of such options.

TNA mitigation technology options with potential water resource/use implications:

Energy sector:

- Higher-efficiency coal-based power generation (more or less water-efficient?)
- Micro-scale hydropower
- Use of bio-fuels

Agriculture sector:

- Production of bio-fuels
- Minimum or reduced tillage

Forestry and land use:

- Plantation forest expansion
- Restoration of degraded rangelands

Waste management:

- Methane recovery from sewage and improved wastewater management

TNA adaptation technology options with potential water resource/use implications:

Agriculture and forestry

- Identifying and addressing direct and indirect threats to food security
- Development and use of new crop species and cultivars
- Macro-economic and livelihood diversification in rural areas
- Improvement in sustainability of land use through, e.g. control and use of invasive species and promotion of agro-forestry

Water Resources

- Technologies that promote water efficiency, such as water pricing; improvement of irrigation efficiency, and reduction in reticulation losses.
- Technologies that promote water recycling
- Groundwater management systems, especially artificial recharge of aquifers
- Inter-basin transfers

Human health

- Adaptation to extreme weather events
- Provision of water supply and sanitation
- Control of the spread of vector borne diseases

Biodiversity

- Biodiversity protection

Fisheries and coastal zones

- Protection of estuarine areas
- Coastal protection, linked to non-excessive groundwater abstraction

Disaster management

- Emergency early warning systems
- Communication and response
- Disaster preparedness
- Vulnerability and risk reduction

Use of financial mechanisms (economic instruments)

- Pollution charges
- Other instruments, such as incentives for energy efficiency and renewable energy, charges on emissions, etc. which may have water resource/use implications of a less direct nature.

The TNA resource document further suggests that an institutional framework for implementation of climate-change mitigation and adaptation technology transfer options be established, with the NCCC preferably playing a co-ordination role in the drafting of an implementation plan. Actual technology transfer should be user driven. Therefore, user involvement should become a prominent component at an early stage. Another critical element is integration with other strategies and policies. Potential contradictions or discrepancies should be resolved before strategies are finally published. Regulatory options, including fiscal and financial incentives that can support transfer and implementation of technologies should be made part of the implementation strategy.

2.2.3.2 A Climate Change R&D Strategy for South Africa

One of the objectives of the National Climate Change Response Strategy is to, "*Ensure that there is an effective and integrated programme of climate change research, development and demonstration in South Africa*."

In response to this overarching national objective, DST has embarked on a process to develop a formal National Climate Change Research & Development (R&D) Strategy. This strategy development process aims to establish a clear basis for funding decisions by DST regarding support for teaching, study and research programmes related to climate change. In other words, the strategy is about priority and focus, seeking the greatest impact from limited funding. Climate change R&D approaches are seen to be needed on three linked fronts: understanding and projecting the change of the physical system; the consequent impacts and development of adaptation strategies; and, mitigation to limit the magnitude in the long term future. These areas overlap and are inter-dependent, and many of the actions would also be necessary within the complementary national objective of sustainable development (i.e., 'no regrets' actions).

The Climate Change R&D Strategy further aims to align climate change R&D activities to address weaknesses already identified in DST's National R&D Strategy of 2002, these being:

- Limited funding;
- Strategic competencies not maintained;

- Human resources in science and technology not adequately developed and renewed, especially relating to black and women scientists;
- Declining R&D in the private sector; and
- Fragmentation of government science and technology.

In considering the strategic context for the National Climate Change R&D strategy, past and current (in 2005) South African climate change projects have been reviewed in terms of the number of projects, categorised by sector and also by whether the projects addressed either impacts and adaptation or mitigation. The largest numbers of such projects were undertaken in the energy, agriculture and water sectors, whilst a significant number also addressed overall projections, policies and measures. Research projects in the energy, housing, transportation, waste, and mining sectors were focused primarily on mitigation, whilst projects in the health, agriculture, biodiversity, human resilience, and water areas, on the other hand, focused more on impacts and adaptation. Recognised weaknesses in the survey were that it was based entirely on the number of projects, neglecting the level of investment (size of project), and also that it omitted to consider foundational research on the climate system at the regional level, upon which all projections of impacts and adaptation measures rely. *[At the time, a significant number of relevant foundational research projects in the atmospheric and oceanographic sciences, culminating in downscaled, regional climate-change scenarios for southern Africa, had been undertaken or were still under way, almost entirely funded by the water sector (Water Research Commission) or from international sources. The most recent multi-disciplinary, multi-institutional studies of climate-change impacts on water resources have relied heavily on this foundational research.]*

Nevertheless, the National Climate Change R&D Strategy, besides serving as the overarching strategic focus for climate change R&D in South Africa, provides for high-level guidance and coordination in the development of sectoral R&D strategies, the water sector included. This framework also assists in clarifying linkages and common denominators among the diverse sectors with regard to climate change R&D requirements and helps to ensure that cross-sectoral interests, in which water is a factor, will be accommodated in the water sector strategy. Specific guidance, of relevance for developing a water-sector strategy, is to be found in the following elements of the national climate-change R&D strategy:

(i) A summary of current climate change research and development areas, issues, research projects and capacity in South Africa, specifically with regard to:

- Science of climate systems, climate variability, and climate change
- Impacts of climate change
- Adaptation to climate change
- Mitigation opportunities with local benefits
- CDM Investment opportunities

(ii) A set of criteria for prioritising future climate change R&D investments

- Address important social, economic and environmental issues in South Africa, particularly those that are specific to South Africa or are unlikely to be adequately addressed elsewhere;

- Facilitate linkages and synergies between mitigation and adaptation aspects of climate change R&D;
- Facilitate linkages between academia, public sector, civil society and the private sector;
- Contribute to building up skills of the next generation of scientists in the major field of CC R&D; and
- Creation of opportunities for regional and international collaboration.

(iii) A classification of high priority themes and objectives for climate change R&D

- ***Human capital development***: Development of the next generation of climate scientists.
- ***Stakeholder engagement, outreach and 'inreach'***: Two-way communication between scientists and end-users in wide range of sectors, to raise awareness and catalyse action
- ***Integrated Assessment Tools and Process***: Provision of an integrating framework for climate change research and policy in SA, driven by user needs
- ***Foundational science of climate systems and climate change***: Building of an understanding of the drivers of climate variability and change; development of a set of plausible climate change scenarios for SA to underpin research on climate change impacts and adaptation.
- ***Impacts, Vulnerability and Adaptation – Cross-Sectoral Research***: Development of an understanding of how communities/organisations respond to current climate variability as a route to better understanding how they might cope with future climate change; enhancement of the capacity of communities, environments and organisations to adapt to climate change
- ***Impacts, Vulnerability and Adaptation – Sectoral Research Projects***: Improvement of sectoral understanding of impacts, especially in response to changes in climate variability metrics; enhancement of the capacity of communities, environments and organisations to adapt to climate change
- ***Mitigation technologies, including the Clean Development Mechanism***: Improvement of sectoral understanding of the potential and enabling environment for CDM projects; identification of mitigation projects that promote sustainable development in SA
- ***Mitigation, economic modelling and sustainable development***: Development of strategies for negotiations on future climate policy obligations with all stakeholders; Identification of large-scale mitigation policies and measures that promote sustainable development in SA

(iv) Explicit or implicit indications of potential water-sector interest in high priority themes

Within each of the above high priority themes, the draft National Climate Change R&D Strategy identifies a comprehensive range of priority topics and potential initiatives. Although relatively few of these themes call for direct water sector involvement, many will, to a lesser or greater degree, have water resource implications and therefore require participation of the water sector in cross-sectoral R&D programmes that address such themes.

Priority topics and potential initiatives identified in the National Climate Change R&D Strategy that could or will require water-sector participation are the following:

- ***Human capital development:*** Considerable human capital development has been accomplished through water-sector support of active participation in research, especially in the areas of foundational research on climate variability and change as well as climate-change impacts on water resources. This could continue and be extended to support for participation in research on vulnerability and adaptation.
- ***Stakeholder engagement, outreach and "inreach":*** Inclusion of the water sector in an integrated regional approach to gathering and disseminating climate-change scenario information and climate-change impacts information to stakeholder networks and fora, may be necessary and an avenue of investigation.
- ***Integrated Assessment Tools and Process:*** Water issues cut across many sectors, which is likely to make water-sector participation an imperative in developing integrated assessments and processes for addressing climate change.
- ***Foundational science of climate systems and climate change:*** The water sector has a long history of supporting research projects in listed priority areas, namely
  - Downscaling of climate change projections to regional level, tailored to end-user (water resources) needs.
  - Describing and understanding correlates and drivers of rainfall variability in southern Africa at seasonal, annual and decadal time scales.
  - Understanding effects of certain land surface feedbacks in regional climate projections.
  - Understanding roles of the oceans and ocean-atmosphere interactions in regulating southern African climate.
  - Quantifying and understanding effects of atmospheric moisture transport on climate variability.
  - Determining historical (palaeo-) climate change processes as a key to understanding future climate change.

  Adequate support from alternative sources may present an opportunity for scaling-down of water-sector support for such (still critical) foundational scientific research.
- ***Impacts, Vulnerability and Adaptation – Cross-sectoral Research:*** Water issues can be expected to be central to research aiming to quantify the limits of current adaptation responses of socio-economic systems and developing future adaptation requirements and responses, assessing vulnerability and resilience of livelihoods to multiple stresses, and refining urban and rural infrastructural planning in order to minimise impacts of and optimise resilience to climate change and other stresses.
- ***Impacts, Vulnerability and Adaptation – Sectoral Research:*** The water sector needs to accept responsibility for continuation of research to improve the ability to:
  - Make projections of impacts on the water sector (including water-linked ecosystems) in response to ongoing refinement of climate scenarios through use of evolving climate models
  - Undertake water resource modelling and management at catchment level, taking into consideration potential climate change-related changes in land use, anticipated demand and supply side impacts, changing pressures on in-and off-channel infrastructure (dams, irrigation), inter-basin transfers, as well as higher order impacts of climate change (e.g. on water quality, aquatic habitats, environmental flow requirements)
  - Manage groundwater protection and utilization, considering groundwater recharge dynamics under climate change; investigate artificial recharge of aquifers as an adaptation measure.

- Manage the impact of climate change on threats to health due to changes in the occurrence and severity of waterborne diseases.
- Develop and refine tools to support water-linked disaster management.

- ***Mitigation: technological, economical and sustainability considerations:*** Mitigation technologies with water resources or water use/demand implications need to be identified and potential water resources benefits and impacts quantified in terms of social, economic and sustainability criteria.

The draft National Climate Change R&D Strategy contains considerable detail pertaining to each of the topics and potential initiatives considered above. Relevant detail has been further considered in the drafting of a recommended portfolio for water-sector supported climate change research.

2.2.4 Strategic Initiatives of Other Government Departments

Examples of government departments that have, besides DEAT and DST, initiated specific climate change-related activities are the following:

The Department of Minerals and Energy (DME): DME has accepted responsibility and been given the legal mandate to serve as the Designated National Authority (DNA) for the Clean Development Mechanism (CDM) in South Africa. The CDM was established in December 1997 by the UNFCCC and allows industrialised countries with emission-reduction commitments to meet part of their commitments by investing in projects in developing countries that reduce greenhouse-gas emissions while contributing to the local sustainable development needs of the host country. Locally, there are 9 registered CDM projects, with a further 10 awaiting approval. The projects cover the following types: bio-fuels, energy efficiency, waste management, co-generation, fuel switching and hydro-power, and cover sectors like manufacturing, mining, agriculture, energy, waste management, and housing and residential. Furthermore, DME produced a White Paper on Renewable Energy in 2003, setting a target of 10 000 GWh of energy to be produced from renewable energy sources (mainly from biomass, wind, solar and small-scale hydro) by 2013. This will ensure a significant reduction in green-house gas emissions and is therefore an important mitigation measure.

The Department of Agriculture (DoA): Following DEAT's publication of the South African National Climate Change Response Strategy, the DoA produced a discussion document that attempts to bring together concepts relating to climate change and the possible effects that it could have on the agricultural sector in South Africa. It is envisaged that this will serve to inform decision makers in current perceptions and follow-up action necessary to address the risks and challenges relating to climate change and agriculture.

The Department of Water Affairs and Forestry (DWAF): Through its designated representative on the National Committee on Climate Change, DWAF has made substantial contributions to national strategies formulated by DEAT and DST and also attends UNFCCC "Conference of Parties" meetings. Furthermore, DWAF, being highly committed to eliminating the backlog of water and sanitation provision to all its citizens and also to promoting integrated water resources management at catchment level, is already well-positioned to provide leadership with regard to enhancing the adaptive capacity of local communities.

DWAF released the first edition of its National Water Resource Strategy (NWRS) in 2005. The NWRS describes how the water resources of South Africa will be protected, used, developed, conserved, managed and controlled in accordance with the requirements of policy and law. The central objective of managing water resources is to ensure that water is used to support equitable and sustainable social and economic transformation and development. With regard to climate change, the NWRS recognises that this has the potential to impact very significantly on both the availability and quality of, and requirements for, water in South Africa. Nevertheless, then current uncertainties in projections saw this 2005 edition of the NWRS adopting a cautious approach to addressing climate change. While acknowledging that climate change should be taken into consideration in the development of catchment management strategies, particularly for those geographic areas that could experience the greatest impact, the NWRS nevertheless advocates seeking a balance between preparedness and overreaction, to prevent valuable resources being wasted. The stated intention is to carefully monitor the situation, giving special attention to selected, relatively un-impacted benchmark catchments and then to formally re-assess needs for specific climate-change response measures with each five-yearly review of the National Water Resource Strategy over the long term.

2.3 South African Legal Framework for Responding to Climate Change

In order for strategic climate-change response initiatives of government to be implemented effectively, the SA governance/institutional framework, especially with regard to environmental policy and legislation, needs to be supportive; this, despite there being no specific mention of climate change in such legislation on account of its having pre-dated the elevation of climate change to an issue of national priority. Because different sectors, working in isolation, could implement mitigation or adaptation strategies that may be non-synergistic or even antagonistic, it is important that strategies be optimised across sectors. Laws that address natural resource management and use should thus promote **integrated** planning and implementation of strategies for addressing climate change issues.

At constitutional level, the full integration of environmental considerations into all stages of development and use of natural resources is accepted as the key to sustainable development. The Constitution lays the basis for Integrated Resources Management (IRM) in statements that everyone has the right to an environment that is not harmful to their health or well-being and that ecologically sustainable development and use of natural resources should be secured, whilst promoting justifiable economic and social development.

Among the various laws that have been enacted, the National Environmental Management Act (NEMA) is the most over-arching and serves as a decision-making framework for all organs of state regarding matters hat might affect the environment. Its principles further provide a basis for the interpretation and administration of all other laws that concern environmental management and protection. These principles include the following:

- Development must be socially, environmentally and economically sustainable
- Environmental management must be integrated, and accepting of the inter-relatedness of all environmental elements

- Decision-making must consider the interests, needs and values of all interested and affected parties
- Social, environmental and economic impacts must be assessed before activities are authorised
- There must be inter-governmental co-ordination and harmonisation of environmentally-related policies, laws and actions
- The permitted use of environmental resources must serve the public interest
- Sensitive or stressed ecosystems need specific attention in management and planning.

More specific national resource-management laws include:

- The National Water Act
- The Development Facilitation Act and Physical Planning Acts (for land use and development)
- The Conservation of Agricultural Resources Act
- The Minerals Act
- The Marine Living Resources Act
- The National Forests Act

The above-mentioned laws each contain principles and make provision for a wide range of management tools and institutional structures, all aimed at achieving sustainable development and use of resources. Some management tools are overarching, such as the Environmental Implementation Plans and Environmental Management Plans as prescribed by the NEMA for government departments concerned with specific resources.

A close examination (by M Uys, in WRC Report KV 176/06) of existing resources management laws and related management tools and institutions in terms of their support for IRM and also, by implication, environmentally-related climate change adaptation measures, revealed a lack of integration needed to support the level of dove-tailing that the NEMA principles dictate. Nevertheless, despite this lack of integration, important attempts have been made to provide for coordination of management systems between national, provincial and local government levels as well as for interdepartmental and multidisciplinary coordination and, furthermore, also for cooperative governance.

The local government (district and local municipal) level is arguably where the greatest degree of integration has been prescribed and is meant to take place. Local governments are, within their areas of jurisdiction, responsible for environmental management, urban and rural planning, water supply and sanitation and disaster management. They are required to produce integrated development plans (IDPs) to address this range of responsibilities. The larger, well-resourced municipalities are gradually learning to cope adequately with this, but smaller, under-resourced municipalities invariably struggle because of a chronic lack of capacity as well as the lack of adequate integration at higher levels of government which results in 'mixed messages' that might detract from the quality of support they receive from those levels.

Within the currently legal framework, obstacles that hamper the move towards effective IRM as called for in the constitution and NEMA, and also necessary for the integrated implementation of climate-change mitigation and adaptation measures, are obstacles such as:

- Uncertainty about the practical meaning and implication of integration, as opposed to coordination, of laws
- Lack of criteria for decentralisation of management tools
- Disparity in emphasis placed on public participation
- Perceived 'newness' of IRM and potential negative impacts of interfering with existing, working systems
- Lack of a common management unit for effective resources management, such as the river catchment.

The concept of catchment management is not included in any of the laws under review, except for the National Water Act, which obligates the Minister to promote the management of water resources at the catchment level and also, in terms of the National Water Resource Strategy, in a holistic and integrated manner. Considering the close linkages between water and other natural resources, the wider acceptance of the catchment as a management unit, not only for water but also for other natural resources, would greatly benefit progress towards IRM. Internationally, this has been happening to varying degrees. In any event, the South African water sector is fortunate to have a governing act that promotes integrative action more so than in most other sector departments. Having said this, the existence in the sector of separate legislation and management frameworks for water resources and water services remains an anomaly which, in the long run, may hamper adaptation initiatives if not attended to.

The concept of public participation is scattered through the various laws with very little effort to demarcate the application of the concept. This leaves the degree and manner of such participation to the discretion of the strategy-formulating authorities in each of the resource departments.

Some suggestions for making the legal framework more climate-change adaptation-friendly and which might be taken forward as potential research topics are the following:

- Progress from the present system of coordinated environmental governance towards a fully integrated resources management system should be facilitated. A prerequisite for this, however, is the harmonisation of the management tools and management institutions in the current laws and management systems for specific resources.
- The catchment should be considered as the management unit for other natural resources as well as water.
- Water resources and water services legislation should be made fully compatible and fully integrated.
- Management systems for different resources should each provide for a uniformly adequate range of management tools. Tools for facilitating public participation are crucial for developing a strong bottom-up thrust that will complement the top-down approach, both being necessary in the drive towards effective implementation of adaptive management approaches.
- Consideration should be given to updating environmental laws to include the specific consideration of climate change and adaptation to impacts of climate change.

3 The South African R&D Context

3.1 Climate Variability and Change: Water Sector-supported R&D

3.1.1 Past WRC-Supported Research

The potential impacts of atmospheric CO_2-induced climate change on the water resources of South Africa was first recognized as a priority area for research in the WRC's Master Plan for Hydrological Research produced in the mid-1980s. At the time it was impossible even to begin to address the topic in a meaningful way because of the lack of scientific capacity and (especially computational) resources. Nevertheless, the role of climate variability in regulating inter-annual water availability and demand was deemed so important, that the WRC identified 'Hydoclimatology' as a research field, deserving of dedicated support and commenced funding research in this area in 1988, initially focusing on mechanisms and teleconnections (especially links with sea surface temperatures) that affect South Africa's climate.

Over a period of almost 20 years roughly R30 million (excluding funding for cloud seeding research) was invested in well over 30 research projects in this field of hydroclimatology. This research (initially under guidance of a WRC strategic plan for hydroclimatological research), included topics such compilation of comprehensive precipitation databases for South Africa, stochastic modelling of precipitation processes, cloud and precipitation physics (including rainfall enhancement), global and regional climate modelling, climate variability studies in relation to ocean-atmosphere processes and teleconnections (including El Niño and La Niña phenomena), precipitation prediction (short, medium and long-term), scale interactions and downscaling. Supplementary funding (in the area of catchment hydrology) provided for hydrological and agrohydrological model development and applications, all of which laid a good foundation for more recent research on the impacts of climate variability and change on South African water resources. Partners in this research have included various departments at the Universities of Cape Town, KwaZulu-Natal, Pretoria, Witwatersrand and Zululand, the SA Weather Service and the Department of Water Affairs and Forestry. Besides the knowledge gained, significant contributions have been made to the development of local climate-related research capacity in climate science and its linkages to water resources.

Apart from research on climate variability and change, WRC-supported research in the area of flood warning is of supreme significance for enhancing local capacity to adapt successfully to an expected higher frequency of extreme precipitation events. Technically, this research has entailed a suite of projects, including the real-time mapping of precipitation fields using a combination of raingauge, radar and satellite monitoring systems as well as the development of rainfall-runoff models suitable for real-time application. Effective flood warning, however, does not only rely on timely availability of reliable flood forecasts, but also on the effective dissemination of, and response to, these forecasts, for which appropriate institutions needed to be designed and put in place – a facet to which the research also made an important contribution.

The first major WRC-funded study focusing explicitly on climate change and impacts on South African water resources, commenced in 2002 and was comprehensively reported

on early in 2005 (**WRC Report No 1430/1/05**). This was a collaborative study, involving research groups at the Universities of KwaZulu-Natal, Cape Town, Witwatersrand and Pretoria, led respectively by Prof RE Schulze, Prof BR Hewitson, Prof C Vogel and Dr F Engelbrecht, while Prof RE Schulze provided the overall coordination. The scope of the study is reflected in the structure of the final report, the substantive sections comprising the following:

- *Background to the Project:* This consists of a single chapter providing background concepts as well as the history of, and rationale behind, the project.
- *Development of Plausible Climate Change Scenarios for Southern Africa:* Four chapters provide the conceptual foundation and uncertainties to the various downscaling approaches adopted, which provide the project with future climate scenarios.
- *An Investigation of the Potential Impacts of Climate Change on Hydrological Responses and Associated Water Resources over Southern Africa:* This section is made up of nine chapters covering the current hydrological "landscape" in southern Africa, the hydrological model selected, the databases which are used as a framework for the impact studies, the impact studies *per se* at the scales of southern Africa and that of a designated Water Management Area, *viz*. the Thukela Catchment, and some case studies.
- *Detection of Climate Change in Southern Africa:* The six chapters making up this section consist first, of a review of, and a description of methods for, detecting climate change, followed by studies on detecting changes in temperature, hydrological responses and rainfall as well as an evaluation of the southern African rainfall station network in regard to detection.
- *Vulnerabilities and Sensitivities of Communities to Climate Risks:* Five chapters make up this section, starting with two chapters on the conceptual framework on vulnerability, adaptive capacity, coping and adaptation, followed by a survey on perceptions of climate change held by different stakeholders in South Africa, a case study on climate change and water poverty and a chapter on case studies on climate and development with regard to farming communities - one operating at small-scale and the other at a large-scale.
- *Adapting to Climate Change in South Africa:* The last technical section of two chapters focuses on policy in regard to climate change and the water sector in South Africa and on adaptations to climate change by the water sector.
- *Synthesis and Recommendations for Future Research:* Take-home messages from the project are highlighted and, based on the outcomes of this project, some recommendations are made for future research.
- *Technology Transfer and Capacity Building:* This section presents the activities of the project team in the fields of relevant publications, workshops attended, presentations made and students trained over the duration of the project from 2003 to mid-2005.

The above-mentioned study has been complemented by another completed study dealing with climate-variability related adaptive capacity and coping strategies of small towns and communities in the Northern Cape, with a view to recommending planning policies and strategies that would ensure water security in the face of future climate change (**WRC Report No 1500/1/06** by P Mukheiber and D Sparks). A water resource management strategy that takes climate change into account would need to include a mix of supply-side and demand-side management strategies and, because of the dependency on groundwater resources in the Northern Cape, would need to focus

largely on groundwater and water harvesting issues. Furthermore, a shift in mindset would be required, i.e. from being reactive to pro-active in dealing with climate variability (particularly drought) and to being more aware of the value of water-resources monitoring. In satisfying needs for locally-based strategies that are socially, environmentally and economically acceptable as well as technically sound, the current lack of climate-change awareness and capacity (personnel, skills, finances) at local level are constraints that would have to be overcome.

These initial projects (as well current projects supported by the water sector and related, externally-supported research generally – see below), besides yielding fresh knowledge and insights, also serve to highlight prevailing knowledge deficiencies and point to further studies that will have to be undertaken before water resource managers and water users across sectors will be secure in the knowledge that the soundest possible adaptation plans and strategies are available and ready for full-scale, practical implementation.

3.1.2 Current WRC-Supported Research

In addition to the ongoing WRC research related to flood warning, four projects that address issues of climate variability and change are currently being funded by the WRC. These are:

- *Predicting the secondary impacts on water resources due to primary changes in precipitation and temperature associated with climate change*
  This project (UCT, assisted by UKZN) continues to refine climate change projections to the regional scale in order to assess the potential secondary effects of climate change on water resource systems, such as effects on factors that influence the health of aquatic ecosystems.
- *Applications of rainfall forecasts for agriculturally related decision making in selected catchments (UKZN)* and
- *Using enhanced knowledge of climate variability for the benefit of water resource management (UCT)*
  These two projects aim to assist managers in the agricultural and water resources sectors to derive maximum benefit from available climate-variability/change-related information, whilst recognising and accepting the levels of uncertainty associated with various categories of information. Optimal utilisation of such information, taking uncertainty into consideration, will reduce sector vulnerability and promote adaptive capacity to variability (short-range projections) and change (long-range projections).
- *Multidisciplinary analysis of hydro-climatic variability at the catchment scale* (UCT):
  This project attempts to throw more light on the oceanic, atmospheric and terrestrial drivers of climate and climate variability at catchment scale, thereby making it possible to reduce levels of uncertainty associated with down-scaled climate forecasts and projections for catchments.

3.2 Recently Completed and Ongoing Research across Sectors

- *Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate Change in the Western Cape (SANBI, CSIR, CSAG (UCT), ERC (UCT) and de Wit Sustainable Options CC.)*

A study undertaken for the Western Cape Government culminated in the above-mentioned report (CSIR Report No. ENV-S-C 2005-073). Water-related impacts and vulnerabilities were identified with regard to water resources including rivers, wetlands and estuaries, as well as livelihoods of people. Key adaptations were found to be necessary in the areas of demand side water-resources management, especially in agriculture. Furthermore, careful review of urbanization rates and urban planning would make sense both for managing current water crises and potential greater competition for fresh water in future. Under a likely drying scenario, development of new water sources, including careful and considered use of aquifers and desalination seem well advised. A strong focus on defense of the ecological reserve is stressed to ensure sustainability of wetland, river and estuary ecosystems. Monitoring of key sites would assist in refining ecological reserve fractions. An assessment of livelihoods underpinned by threatened natural resources would usefully guide policy to improve their adaptive capacity. Overall, the work presented is an initial, broad overview of the problem posed by projected climate change, and requires further attention to detail in many areas before clear guidelines on adaptive strategies can be drawn. Further focused study is needed, mainly to reduce uncertainties in many areas relating to the climate projections themselves, and of inferences of impacts and sectoral vulnerabilities (especially water, urban development, natural ecosystems, and livelihoods).

- *Development of Regional Climate Change Scenarios for Sub-Saharan Africa (AIACC project AF07).*
  As lead institute on this project the CSAG (UCT) developed downscaled climate change scenarios for southern and South Africa. This was accomplished using both Regional Climate Models (RCMs) and statistical downscaling methods. The downscaling results using RCMs were found to be dependent on the model configuration with statistical techniques providing information of similar quality and at similar spatial scales (25 km). These climate change downscalings are available for 6 GCMs for the whole of the Western Cape and comprise one of the highest resolution and comprehensive datasets available for climate change policy and adaptation development in this region. Furthermore these downscalings, conditioned on changes in the regional dynamics, reduce the uncertainty inherent in the GCM rainfall, whilst allowing the uncertainty to be easily quantified across multiple models. These data were used in AIACC Project AF 47 as the climate forcing inputs for a hydro-economic model of the Berg River basin to estimate the physical and economic impacts of climate change and the net benefits of alternatives for adapting to climate change.

- *Capacity Building in Analytical Tools for Estimating and Comparing Costs and Benefits of Adaptation Projects in Africa (AIACC Project AF 47).*
  One of the case studies in this project was devoted to developing an integrated climate-hydrology-economic model, the Berg River Dynamic Spatial Equilibrium Model (BRDSEM). The Berg River Basin, the water source for a large share of South Africa's agricultural export industry and for the bulk of the population in metropolitan and suburban Cape Town, is situated in a region where precipitation is fairly consistently projected to decrease due to climate change. BRDSEM was developed specifically for this region to help water policy-makers and planners to examine the physical and economic impacts of rapid population growth and climate change; to assess the physical and economic benefits and costs of structural and

non-structural measures for coping with both these problems; and to estimate the economic value of the physical damages that could be avoided by these options.

- *Adapting to climate, water and health stresses: Insights from Sekhukhune, South Africa (The Stockholm Environment Institute (SEI) and UCT's CSAG).*
  The investigation reported in this SEI report links to an impressive array of work being funded and undertaken collaboratively by a range of interests, including the SA Department of Agriculture and the HSRC (the Food Insecurity and Vulnerability Information Mapping System or FIVIMS), locally-based organisations (CAVES and AWARD) and the EU-funded Caves Project. Fieldwork carried out at Sekhukhune district, municipal and village levels sought to develop an understanding of the responses at these levels to multiple stresses. The findings indicated that water scarcity (linked primarily to climate stress but also to issues of water management and household and agricultural water provision) and limited employment opportunities were the major constraints that undermine food security and adaptive capacity. This highlights the need for integrated responses to support local adaptation to multiple stresses (including those that are climate change-related) and to move away from the usual sectoral approaches. It also requires improved and increased communication between government and local communities to facilitate the integration of strategies to be implemented at different scales and better align expectations.

In addition to the research project outcomes briefly summarised above, the National R&D Strategy lists an additional number of research initiatives relevant to reducing vulnerability and enhancing adaptive capacity to climate change in South Africa. These are:

- University (Wits and UCT) studies on adaptation to climate variability and change in Limpopo (north and south), North West, Northern Cape (Suid Bokkeveld), eastern Karoo.
- The South African Vulnerability Initiative (SAVI).
- Disaster management research (UCT Disaster Management Programme, Wits, UKZN).
- Conservation strategies for adaptation (SANBI, University of Stellenbosch, Wits).
- Studies of changing livelihoods, migration, urbanisation and social attitudes to environmental issues (HSRC).

A useful resource for obtaining further detail concerning recent and current research projects that address climate change and related issues is the NEXUS database maintained by the National Research Foundation.

3.3 Newly-initiated or Anticipated Research of Water-sector Relevance

3.3.1 Newly Initiated Climate-change Related Research

- *Managing climate risk for agriculture and water resources development in south-western South Africa: Quantifying the costs, benefits and risks associated with planning and management alternatives (Dept of Agricultural Economics of the University of Free State with major inputs by CSAG (UCT) and contributions by other local and some international partners).*

The general objectives of this newly initiated work, funded by the International Research Development Centre of Canada under its Climate Change Adaptation in Africa (CCAA) Programme, are twofold, namely: (i) to develop the capacity of South African and regional (Western Cape) institutions in the private and public sectors to better integrate information about climate change and climate variability into water resources policy, planning and management; and (ii) to demonstrate how this information can be used to evaluate alternative strategies and projects for adjusting/adapting to climate change and climate variability for application in other regions (these will include adaptation strategies for resource-poor and emerging farmers). More specific objectives are the following:

- The institution of a programme of stakeholder involvement, capacity building and awareness raising that will develop and promote assessment tools and methods to fit the specific needs in the region, South Africa and Southern Africa, specifically water policy makers, water planners, water managers and users.
- The institution of a research programme that will develop and demonstrate integrated assessment methodologies for evaluating the benefits, costs and risks of water resource adaptation projects in the Cape Winelands (or Boland) District in the Western Cape of South Africa, congruent with stakeholder needs.
- The implementation of an innovative research approach to adaptation that will combine an economic evaluation of adaptation alternatives with an investigation of the extent to which stakeholders in the Western Cape can adjust to climate change by first adjusting to seasonal and multi-decadal climate variability.

3.3.2 Climate-Change Related Research under Consideration

3.3.2.1 To be supported by the Water Research Commission

In its 2007 call for research proposals, the WRC provided terms of reference for three solicited projects that would commence in 2008 and, if successfully executed, would contribute meaningfully to the capacity of the water sector to adapt to climate change. These are:

- *Identification, quantification and incorporation of risk and uncertainty in water resource management tools*
  This project seeks to develop a sound understanding of risk and uncertainty in water resources management, to identify and characterise sources of risk and uncertainty, to develop techniques and tools for quantification and communication of the risks and uncertainties and to advise on how uncertainty can be reduced or mitigated in various water resources practices and how quantified risk can be incorporated into decision making processes. Risks and uncertainties may arise from numerous factors, including inadequate climate data and information, climate variability and change, spatial and temporal downscaling and upscaling errors, reliability of water-use data and water demand projections, model structure and parameterisations, modeling skill, etc.

- *An evaluation of the sensitivity of socio-economic activities to climate change in climatically divergent South African catchments*
  Specific objectives are to select four climatically divergent catchments and, for these, to establish the likely biophysical changes associated with projected climatic changes, determine the socio-economic activities that are at risk, develop current

and projected water resource accounts, calculate the sensitivity to change and capacity for adaptation in current socio-economic activities, quantify the likely socio-economic impact taking into account socio-economic resilience and adaptive capacity and, ultimately, propose appropriate policy responses and strategies to assist communities in adapting to climatic change.

- *Integrating water resources and water services management tools*
  Currently water resources and water services are governed and managed under separate Acts, namely the National Water Act (1998) and the Water Services Act (1997), while water management and use, in the broader environmental and sectoral context, is the responsibility of various government ministries and institutions. This project will initiate a multi-disciplinary approach to IWRM that includes addressing water resource and water service issues in an integrated fashion. A key focus will be the integration of management tools currently being employed, as separate entities, in water-service and water-resource applications. What is ultimately required is the identification of an optimal pathway to complete integration that could appropriately inform possible legislation and policy changes.

3.3.2.2 To be supported from sources other than the Water Research Commission

At least three useful project proposals that stand a good chance of gaining support are currently under funding-agency consideration. Because of confidentiality, detail is restricted. The projects are:

- *Mainstreaming climate variability and climate change into policy and decision processes for adaptation in water resource management*
  The aim of this research is to jointly develop a framework, based on experience, by which the capacity of South African national and local institutions to consciously adapt to increased climate variability associated with climate change could be enhanced. This will be achieved by designing transitions and innovations linked to an integrative adaptive water management approach during round table discussions/workshops to be held with water managers and relevant stakeholders. In this way adaptation measures could be mainstreamed into daily routines of water managers, enhancing their capacity to respond to climatic changes and stresses.

- *Stochastic, space-time modelling of rainfall*
  Research of this nature is important for characterising and representing simultaneously varying patterns of spatial and temporal rainfall variation under stationary climatic conditions and for providing a sensitive method of detecting climate-change impacts on spatial and temporal variability of rainfall.

- *Using catchment climate scenarios to support adaptive learning within CMAs and WUAs*
  A project to be undertaken by DWAF in collaboration with UCT, the Stockholm Environment Institute and Environment Agency (England and Wales), is under consideration to commence in 2008.

4 A Framework for Identifying, Analysing and Communicating Climate Change-related R&D Needs and Actions Involving the Water Sector

The framework presented here reflects the scope and distribution of R&D responses to needs considered by stakeholders to be worthy of consideration in order to enable the water sector, in partnership with other sectors wherever appropriate, to effectively meet challenges and responsibilities posed by global climate change and its regional expression. These responses are broadly categorized under the headings:

- assessment of climate-change impacts
- adaptation to climate-change impacts, and
- mitigation of climate change through greenhouse-gas reduction or sequestration.

The framework detail represents the outcome of a process that included consideration of recently published and unpublished official reports and related documents (IPCC, international and national reports and strategy documents), consultation with and solicitation of comment from a broad range of stakeholders, and the holding of a stakeholder workshop to, among others, refine the framework and its contents.

Identification of the highest-priority research topics within the framework (see next section, i.e. Section 5) was a further major task of the above-mentioned workshop, which also sought to advise on the development of research projects to address these topics.

The framework and suggested research topics as presented below essentially represent the input to the stakeholder workshop following refinement, but prior to any attempt at prioritisation.

4.1 R&D Needs Related to Impacts of Climate Change

4.1.1 Refinement and Communication of Climate-change Scenarios, Projections, Information and Data

Advances in climate science internationally and nationally provide opportunities for:

- refining regional climate-change scenarios or projections, down-scaled to spatial units meaningful for water-resource and water-use related impact identification and quantification.
- producing quantified estimates of levels of reliability associated with downscaled projections and of climate information in general
- distinguishing between climate change and climate variability.

An important question to consider is: who should take responsibility for satisfying the needs of the water sector (and every other climate-sensitive sector) for regular production and communication of refined climate-change data and information, tailored to meet the needs of the sector? In the UK this role has been assigned to the Climate Impacts Programme (UKCIP). Having a single agency fulfill this responsibility is advantageous in that it provides for consistent climate-change projections for all sectors to use in assessing impacts. This also provides a common base for the integrated

assessment of net impacts across sectors, especially with regard to crosscutting issues such as water resources and water utilisation.

Possible Projects

1. *Investigate the role of the water sector in facilitating, participating in and/or supporting a single-agency approach (e.g. a Climate-Change Information and Support Centre similar to the UKCIP) where users in various sectors are able to obtain updated, refined and possibly conditioned data and information for the ready revision of climate-change impact assessments.*
2. *Periodic review of future climate change scenarios and projections to allow for refinement of assessments of water-associated climate-change impacts, made possible by probable improvements in climate modeling tools and downscaling tools and the coupling of atmospheric and hydrological models.*
3. *Improving hydro-meteorological networks in a manner that will permit natural hydro-meteorological variability to be distinguished from climate-change impacts and ultimately support the validation, refinement and application of hydrological forecasting models.*
4. *Development of a stochastic model that is able to capture and reliably reproduce current space-time stochastic behavioural properties of rainfall. Model trends from one decade to the next would assist in the earliest possible detection of any systematic changes in rainfall patterns and in projecting the changing pattern of rainfall variability into the future. Combined with other robust statistical techniques these may assist in distinguishing between natural variability and change in 'noisy' environmental data sets.*
5. *Regular updating of climate trend and change scenarios generated with regional atmospheric models. The performance of these models in reproducing current climate and capturing currently observed trends in temperature, rainfall and other variables might contribute to enhancing confidence in the ability of these models to simulate future climate change scenarios. In the process, boundary input such as lateral boundary meteorological feed, as well as land-use characteristics, need to be optimised.*
6. *Facilitation of communication to, and best-use of climate and climate-variability information (including forecasts, predictions and outlooks) by, agricultural and water resource managers, to reduce short and long-term vulnerability of local economies to variability and change (Some research already in progress).*

4.1.2 Identification and Quantification of Impacts

4.1.2.1 Sectoral and Inter-sectoral Impacts

R&D needs related to quantification of impacts of climate change on water resources and water utilization, and implications (cost-assessments) for single and multiple sectors, at catchment or water-management unit level. Impacts to be considered are:

- **Direct impacts on water resources:** e.g., runoff (including extremes, i.e. flooding, drought), dam yield, aquifer recharge and yield.

Possible Projects

1. *A data mining and modelling campaign to test the ability of existing water supply and flood defence infrastructure (flood lines, river regulation) to cope with the full range of natural variability (especially known historic extremes), as the first step in climate-proofing.*
2. *Refining and enhancing accuracy of hydrological (including geohydrological) prediction models. For identical future climate inputs, use of a range of water resource models typically give rise to poor agreement and consequently large uncertainties in the reliability of outputs, possibly owing to the use of different model structures and parameterisations resulting from the poorly characterised or partially understood representation of natural processes in the models.*
3. *Instituting reliable hydrological monitoring systems, also including remote sensing techniques in hydrological monitoring.*

- **Indirect impacts on water resources, through:**
  - Impacted land-use and consequent streamflow enhancement/reduction
  - Impacted ecosystems (rivers, lakes, impoundments, wetlands and estuaries)
  - Impacted water demand and usage (with and without implementation of adaptation/mitigation strategies) by all sectors.

Possible Projects

1. *Development of tools for evaluation of water-resource-development risk factors attributable to climate change.*

- **Sectoral/intersectoral implications of climate change-related impacts on water resources**
  - Municipal/domestic/built environment
  - Health
  - Ecological reserve
  - Agriculture
  - Energy
  - Mining
  - Industry
  - Other (e.g. recreation).

Possible Projects

1. *Continuous refinement of agriculturally-relevant regional climate-change scenarios (i.e. scenarios including information on likely changes in crop energy balances, growing season conditions, etc.) that either impact on water use of rainfed and irrigated agricultural crops or provide benefits to agricultural production.*
2. *An initial but comprehensive national assessment of impacts of climate variability and change in the health sector, focusing specifically on water related illnesses. (Such a project may be deemed urgent since it is known that vectors and parasites flourish under currently prevalent conditions of environmental degradation and change.)*

- **Direct and indirect impacts on water quality/pollution (salinity, chemical and microbial, with and without implementation of adaptation/mitigation strategies), together with sectoral/intersectoral implications:**

  - Municipal/domestic/built environment
  - Health
  - Ecological reserve
  - Agriculture
  - Energy
  - Mining
  - Industry
  - Other.

Possible Projects

1. *Initiation of a programme to investigate effects of climate change on water quality aspects, including:*
   - *Salinity changes due to increased and decreased streamflow (depending on the region and projected climate scenario)*
   - *Suspended sediment load changes due to more intense rainfall events (with impacts on dam sedimentation rates, transport of sediment-bound pollutants, mechanical stressors of biota etc.)*
   - *Increased water temperature (and effects of decreased dissolved oxygen on fish and other aquatic life; increased algal blooms in dams, rivers and canals - with increased duration and extent of toxic algal events)*
   - *Spread in extent of disease vectors and prevalence of microbes under conditions of climate change, and consequent impacts on disease (vector-borne, water-related as well as water-borne and water-scarce disease)*
   - *Increased toxicity of some constituents of water quality (such as ammonia) under higher temperatures affecting fish and other biota*
   - *Monitoring of pristine sites (chemical, biological, toxicological etc.) in order to see what the long term CC-induced changes will be without the confusing effects of landuse change on the water resource potentially masking the effects of CC.*

4.1.2.2 Cross-sectoral Impacts (i.e. within Regions, Communities)

Cross-sectoral research needs are considered to be those that are best addressed by a range of investigators from different sectors working, together with local stakeholders, as a team to holistically assess the overall climate-change impact on a system, which may then be expressed in economic or other appropriate terms. From a water perspective, all interacting climate-change-related demands and impacts on water resources and supplies will be accommodated in such an approach. Systems may represent either sensitive ecosystems, socio-economic regions (such as provinces or district municipalities), or vulnerable communities.

Experience has already shown that water is often at the heart of that complex of impacts that causes a region or a community to be vulnerable to climate change; the question, therefore, is to what extent water sector funding should be used to initiate or at least to partially support water-sector participation in meeting research needs of this nature.

What specific R&D needs in this category, if any, should therefore be addressed in a water sector R&D portfolio?

- **Direct and indirect impacts of climate change on ecosystems and ecosystem goods and services, as well as on beneficiaries of such goods and services**

- **Direct and indirect impacts of climate change on specific socio-economic regions**

- **Direct and indirect impacts of climate change on specific local communities**

Possible Projects

1. *Comprehensive appraisal of water-associated risks (potential impacts, linked to exposure and vulnerability) related to rising temperatures in all sectors and biomes (air, river, ground, estuaries, and coasts).*

4.2 R&D Needs Concerned with Adaptation to Climate Change

Following the example of the UKCIP, the adaptation process may be divided into two distinct sub-processes, each of which will require R&D support. These are:

- *Enhancing adaptive capacity:* This involves creating the appropriate information, skills and favourable conditions (policy and legislation, regulatory, institutional, managerial) required in order to maximize the effectiveness of adaptation actions.
- *Delivering adaptation actions:* This involves taking actions that will help to reduce vulnerability to climate risks, or to exploit opportunities.

In practice, these processes form a continuum, but it is nevertheless helpful to distinguish them since sufficient existing capacity would generally be a prerequisite for successful implementation of adaptation options.

4.2.1 Enhancing Adaptive Capacity

To what extent would it be important/necessary for the water sector to engage with other relevant sectors and stakeholders in researching and developing decision-support tools for the following?

- Creating a supportive/enabling institutional environment: needs in this regard may span a range of levels, from the harmonization of laws and institutions at national government level (refer to Section 2.3 of discussion document), to the development of coordinated climate-change response strategies at government department level, to the building of bridges between successive levels of government and between government and local communities
- Providing appropriate incentives for adaptation
- As a precursor to building appropriate adaptive capacity, assessing multiple risks and vulnerabilities associated with current and future stressors related to potential impacts
- Creating awareness of risks/costs of non-adaptation and opportunities/benefits of adaptation

- Selecting appropriate adaptation approaches from a range of possible options (e.g. bearing potential losses; sharing losses through insurance-type approaches; structural/technological options; legislative/regulatory/institutional options; socio-economic interventions)
- Providing appropriate information and early warning systems
- Addressing socio-economic constraints (poverty, access to land and services, sustainable livelihoods, etc.)
- Addressing infrastructural and technological needs
- Building managerial capacity at all appropriate levels.

Possible Projects

1. *Harmonisation of national laws and development of appropriate institutions to facilitate integrated, multi-sectoral initiatives at national, provincial and local government levels for addressing vulnerability and adaptation to climate change in rural economies and communities.*
2. *Development of a generic climate-change response strategy for DWAF and catchment management agencies. This is needed to inform the next revision of the National Water Resource Strategy, which is committed to addressing climate-change issues in greater depth than the current NWRS.*
3. *Development of a comprehensive water-use database to assist in monitoring of shifting patterns of water use (including effectiveness and efficiency), thus enabling developing imbalances and vulnerabilities to be detected at an early stage and necessary adaptations to water utilization plans to be made.*
4. *Compilation of a comprehensive database on impacts and responses to current extreme weather events (which are expected to become the normal experience later in the century).*
5. *Identification, description, classification, evaluation and ranking of water-associated sensitivities and vulnerabilities (social, economic, environmental) to climate change at the catchment scale.*
6. *Development of appropriate climate-change and adaptation indicators for incorporation into water resources planning and monitoring systems where there may be interaction (synergies, trade-offs) between national, inter-sectoral and intra-sectoral climate-change mitigation and adaptation measures in as far as they relate to water resources. Where potential mitigation and adaptation interventions address many sectors, the use of Life Cycle Analysis (LCA) may be considered to assist in their overall evaluation.*
7. *Assessment of applicability/potential benefits, as adaptation measures, of **technologies** that could enhance **water availability** in stressed areas, such as:*
   - *Inter-basin transfers*
   - *Rainfall enhancement (cloud seeding)*
   - *Fog and rainwater harvesting*
   - *Harvesting/storage of runoff water.*
8. *Assessment of applicability/potential benefits, as adaptation measures, of **technologies** that promote **water use efficiency and conservation**, such as:*
   - *Water pricing*
   - *Improvement of irrigation efficiency*
   - *Reduction in reticulation losses*
   - *Water recycling (grey water, use of small-scale treatment units)*
   - *Stormwater and rain-water harvesting*

- *Effective storage of water collected from rain and fog for domestic and sanitation use.*
- *Managed groundwater recharge schemes*
- *Use of renewable energy (indirect, through reduced dependency on water use in electricity generation).*

9. *Assessment of the adaptation potential of reclaiming degraded land (i.e. reversing desertification) for restoring rural livelihoods, protecting biodiversity, and reducing impacts on groundwater and water quality.*
10. *Assessment of the feasibility of extending water-associated disaster management measures to include risk and vulnerability reduction measures such as through the development of new insurance products or other innovative solutions, e.g. for vulnerable communities, such as informal settlements located on flood plains. This would require more research into quantification of the risks of extreme events as well as the financial implications for different socio-economic groups.*
11. *Development of integrated tools and measures to assess the effectiveness and efficiency of adaptation measures. For example, research should help to design tools that demonstrate the integrated social, environmental and economic benefit and cost-effectiveness of adaptation at appropriate scales, and to develop indicators for successful adaptation measures.*
12. *The facilitation of (i) awareness-creation among local rural communities of the impact of climate variability and change on their vulnerability to multiple stressors (e.g. poverty, water availability, access to agricultural resources, etc.) and (ii) setting up of appropriate local institutions to empower communities to interact with government in addressing issues of vulnerability and adaptation.*
13. *Understanding the effects of climate change on biodiversity of water-linked ecosystems as well as on ecosystem goods and services, in order to best manage impacts and introduce adaptation measures.*

4.2.2 Delivering Adaptation Actions

4.2.2.1 Adaptation of water-resource and water-use planning/management

To what extent is it necessary to provide research support to national, regional and local custodians of the country's water resources with regard to the following?

- Building climate variability and climate change considerations into water resource development planning for a range of time horizons
- Building consideration of climate variability and change into water use licensing arrangements, water allocation and water demand management
- Building consideration of climate variability and change into water resource protection measures (RDM; i.e. classification, the reserve, resource quality objectives, etc.) for surface water, groundwater, wetlands, estuaries, etc.

Possible Projects

1. *Building resilience to climate variability and change into catchment management plans.*
2. *Potential of adapting to climate change through water re-allocation, i.e. from uses that generate less total value (social, environmental, economic) per unit of water consumed, to uses that generate more, as well through the use of 'virtual water'.*

3. *Adapting key water resource management strategies (e.g., resource classification, the reserve, resource quality objectives, resource allocation, licensing provisions) to account for climate change impacts during the course of the periodic revision of the National Water Resource Strategy.*
4. *Identification and accelerated implementation of a suite of "no-regrets" adaptation strategies (such as IWRM). These are strategies, many already incorporated in development plans, that carry with them a strong likelihood of increasing the resilience of people and/or systems to impacts of climate variability and change but which, for various reasons, may have been delayed or placed on hold.*

4.2.2.2 Support for cross-sectoral action at regional/catchment/community level

To what extent is it important/necessary for the water sector to partner with other relevant sectors and stakeholders in developing/refining/implementing guidelines and decision tools for the following adaptation-supporting actions?

- Selecting and prioritising specific case studies for maximum impact and transportability of results
- Planning and implementing pilot-scale demonstration projects, including consideration of issues such as mentoring, monitoring, evaluation against appropriate indicators and sustainability.

Possible Projects

1. *Optimisation, for specific cases, of cross-sectoral adaptation measures involving water, with the aid of cooperative governance and modified institutional arrangements, integrated environmental management programmes, disaster management and social upliftment programmes.*
2. *Determination, within case-study context, of the added value of a package of water-related climate-change adaptation measures including improved water storage, treatment and supply, appropriate sanitation provision and hygiene practice (already a national priority and important for the control of water borne diseases)and controlling water pollution in reducing stress on, and enhancing resilience of the rural poor.*
3. *Countering the combined risk to coastal environments (aquifers, estuaries and wetlands) and environmental goods and services resulting from climate change, sea level rise and coastal land-use practices.*
4. *Building on the outcomes of investigations to date, the development (provision) of generic decision-support guidelines for rapidly identifying and prioritizing key vulnerabilities and adaptation requirements of specific local rural economies and communities.*

4.3 R&D Needs Concerned with Mitigation of Climate Change

- Various sectoral mitigation initiatives or strategies (including those related to CDM projects) might have water resources or water use/demand implications and therefore require a measure of R&D involvement by the water sector, for example:

  Energy sector:
  - Higher-efficiency coal-based power generation (how water-efficient?)
  - Micro-scale hydropower

- Development and use of bio-fuels and other environmentally friendly fuels

Agriculture sector:
- Production of bio-fuels
- Minimum or reduced tillage

Forestry and land use:
- Plantation forest expansion
- Restoration of degraded rangelands

Waste management:
- Methane recovery from sewage and improved wastewater management

To what extent do these need to be identified and potential water resources benefits and impacts quantified in terms of social, economic and sustainability criteria?

- Are there opportunities for the water sector to participate in the CDM arrangement?

Possible Projects

1. *Development of appropriate climate-change and adaptation indicators for incorporation into water resources planning and monitoring systems where there may be interaction (synergies, trade-offs) between national, inter-sectoral and intra-sectoral climate-change mitigation and adaptation measures in as far as they relate to water resources. Where potential mitigation and adaptation interventions address many sectors, the use of Life Cycle Analysis (LCA) may be considered to assist in their overall evaluation.* (Repeat of Possible Project 6 in Section 2.1).
2. *Quantify the links between energy and water-use efficiency.*

5. Towards a Climate-change Research Portfolio for the Water Sector – Recommendations of the Stakeholder Workshop

5.1 Criteria for Prioritisation of Suggested Research Topics

In its draft of *A Climate Change R&D Strategy for SA*, DST proposed a set of criteria for the prioritisation of future climate change R&D investments. In terms of these criteria, slightly modified as a result of stakeholder feedback, future R&D initiatives should:

- Address important environmental, social, and economic issues in South Africa, particularly those that are specific to South Africa or are unlikely to be adequately addressed elsewhere;
- Facilitate linkages and synergies between mitigation and adaptation aspects of climate change R&D;
- Facilitate linkages between academia, public sector, civil society and the private sector;
- Contribute to building up skills of the next generation of scientists and managers in the major field of CC R&D; and
- Creation of opportunities for transnational, regional and international collaboration.

These criteria are equally appropriate for assisting in the selection of R&D initiatives that merit water sector support and as such, have been brought into consideration.

5.2 Workshop Process for Identifying Potential Research Projects of High Priority

Four areas of the R&D framework (i.e. the framework for identifying, analysing and communicating climate change-related R&D needs and actions involving the water sector – see Section 4) received separate consideration in the process of capturing high-priority research topics. They were the following:

1. R&D Related to Impacts of Climate Change

Area 1 – **Allocated to Group 1 for consideration**		
1.1	Refinement and Communication of Climate-change Scenarios, Projections, Information and Data	
1.2	Identification and Quantification of Impacts	
	1.2.1	Sectoral and Inter-sectoral Impacts
	1.2.2	Cross-sectoral Impacts (i.e. within Regions, Communities)

2. R&D Concerned with Adaptation to Climate Change

Area 2 – **Allocated to Group 2 for consideration**
2.1 Building Adaptive Capacity

Area 3 – **Allocated to Group 3 for consideration**
2.2 Delivering (Piloting) Adaptation Actions
2.2.1 Adaptation of water-resource and water-use planning/management
2.2.2 Cross-sectoral adaptive action at regional/catchment/community level

3. R&D Concerned with Mitigation of Climate Change

Area 4 – **Considered by workshop plenary**

The ideal outcome of the consideration given by workshop participants to R&D needed in each of the above areas would have been the following:

- A limited number (2-4) of highest priority projects within each area identified
- Scope and objectives of each project defined
- Urgency and desirable time frame indicated
- Possible capacity constraints identified
- Desirable partnerships (national/international) indicated.

Owing to time constraints, however, not all of the above-mentioned facets could be accommodated. Nevertheless, the initial prioritisation of projects that has been achieved provides a valuable departure point for further development of detailed terms of reference of projects deemed to be of greatest importance and/or urgency.

5.3 Results of Prioritisation Exercise

Area 1: R&D Related to Impacts of Climate Change

Section 1.1 Refinement and Communication of Climate-change Scenarios, Projections, Information and Data

Priority 1:

Investigate the role of the water sector in facilitating, participating in and/or supporting

a single-agency approach (e.g. a Climate-Change Information and Support Centre similar to the UKCIP) where users in various sectors are able to obtain updated, refined and possibly conditioned data and information for the ready revision of climate-change impact assessments.

Points to consider when developing terms of reference:

- The support centre is not intended to fulfil the role of a one-stop shop, but should serve as a unified interface between climate modelers, impacts modelers, policymakers etc. Currently scientists are frustrated by available information not getting to users, while policymakers are frustrated by poor access to scientists and scientific knowledge.
- It will be necessary to undertake preparatory research/scoping before launching the Centre.
- The support Centre needs to consider the mandates and policies of existing structures (e.g. the National Disaster Management Centre, Government Departments) to avoid duplication or interference and rather link to them in a way that seeks to create synergy.
- The Centre needs to be at arms length from government, which may, however, set the operating parameters.
- The Centre will need a technical subcommittee as well as a governance subcommittee, while a steering committee with strong government department representation is suggested.
- The Centre will be primarily a national initiative with some international outreach/ involvement.
- This Centre will communicate the certainty/uncertainty around projections of change, rather than try to provide all the answers in terms of impacts.
- The Centre, in responding to requests for information, should have the ability to guide stakeholders who are not well-informed in developing a common understanding of what the real issues are. Otherwise, responses might be inappropriate.

Urgency:	Very urgent, immediate need.
Time frame:	Needs to run for a sustained period e.g. 3-4 years for evaluation.
Partnerships:	The WRC could be a part funder, considering that many climate-change issues relate to water resources and water utilisation.
Note:	The suggested project: *Facilitation of communication to, and best-use of climate and climate-variability information (including forecasts, predictions and outlooks) by, agricultural and water resource managers, to reduce short and long-term vulnerability of local economies to variability and change* (No 6 in list of suggested projects), could be considered to fall within the scope of this project. The assumption (which should be checked) is being made that dissemination of historical data is catered for elsewhere (possibly through SAEON)

Priority 2:

Research on and periodic refinement of regional projections including uncertainty analysis to allow for refinement of assessments of water-associated climate-change impacts, made possible by probable improvements in climate modeling tools and downscaling tools and the coupling of atmospheric and hydrological models.

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Points to consider when developing terms of reference:

- New releases of projections will probably be needed on a three year cycle; these should be made through the Centre to be investigated under Priority 1

Urgency:	Must be in place before the above-mentioned Centre (Priority 1) is instituted
Time frame:	1 year (repetition at 3 year intervals, as required)
Capacity constraints:	Research capacity w.r.t. uncertainty analysis
Partnerships:	WRC should take overall responsibility, in partnership with DST and others, with NRF providing student support.

Lesser priority

Improving hydro-meteorological networks in a manner that will permit natural hydro-meteorological variability to be distinguished from climate-change impacts and ultimately support the validation, refinement and application of hydrological forecasting models (Project No 3 in list of suggested projects).

- Whilst of considerable importance and urgency, this is essentially a function of DWAF and the South African Weather Service and thus of lesser priority from the R&D perspective. WRC support may be required where certain aspect of the research.

Section 1.2 Identification and Quantification of Impacts

General comment

In this section the higher priorities were awarded by the workshop participants to sectoral, as opposed to inter-sectoral and crossectoral research. Consequently, a sizeable component of Subsection 1.2.1 and the whole of Subsection 1.2.2 are not represented in the research topics/projects identified below (see Section 4.1.2 for detail of scope).

Prioritisation

Priority 1:

Direct and indirect impacts on water quality

Points to consider when developing terms of reference:

- Influence of changes in water temperature relates to many ecological/water quality variables
- Apply scenarios to water quality algorithms related to human consumption/health

- Research needs also to investigate water bodies, evaporation-concentration effects, persistence of microbes/pathogens, sediment-related water quality (e.g. P, N loads), parasites (also bearing in mind seasonality).

Urgency:	Immediate
Timeframe:	3-5 years
Capacity constraints:	Technology transfer (e.g. to municipalities), implementation
Partnerships:	WRC, DWAF, CSIR, academics

Priority 2:

Direct and indirect impacts on the Environmental Reserve

Points to consider when developing terms of reference:

- Instream flow requirements need to be considered under both maintenance and drought conditions
- Indicators of hydrologic alteration need to be identified and applied (numerous indicators)

Urgency:	Medium to long term, but necessary to maintain existing momentum
Timeframe:	3-5 years
Capacity constraints:	high (expertise, monitoring)
Partnerships:	WRC, DWAF, academics

Priority 3:

Direct and indirect impacts on extremes of flow

Points to consider when developing terms of reference:

- Focus to be on floods and droughts: determination of changes in the magnitude and frequency of design events, vulnerability of humans and aquatic/terrestrial ecosystems to extreme events and associated health impacts

Urgency:	Not indicated
Timeframe:	Not indicated
Capacity constraints:	Not indicated
Partnerships:	Not indicated

Priority 4:

Direct and indirect impacts on groundwater

Points to consider when developing terms of reference:

- Recharge including water quality issues such as fate and transport of pathogens
- Fast responding aquifers (e.g. dolomite) versus slow responding aquifers, with regard to water quality

Urgency:	Urgent (also for reasons not necessarily related to climate change), but medium term
Time frame:	Not indicated
Capacity constraints:	High
Partnerships:	WRC, CSIR, UWC, UFS, UP

Area 2: R&D Related to Enhancing Adaptive Capacity

Pre-prioritisation discussion

1. The first point to be made was that some capacity to adapt to climate variability and change already exists in different measure throughout various tiers of society, although such capacity is likely to fall far short of that needed to address growing challenges related to global (including climate) change. Therefore, instead of *'Building Adaptive Capacity'* as originally titled, this element of the R&D portfolio is more appropriately named *'Enhancing Adaptive Capacity'* since the former might imply little or no prior adaptive capacity. The R&D framework (Section 4) has been revised to reflect this refinement.
2. The next point to be made was that useful research into enhancing adaptive capacity cannot be the domain of a single sector. Consequently, multi- and cross-sectoral partnerships should be actively sought when planning and executing such research.
3. The final point to be made was that the examples of initiatives for enhancing adaptive capacity that would possibly require R&D support, as tabled, as well as the tabled list of possible research topics, appeared to be largely random and not related to any research-needs framework that could assist in meaningful prioritisation of R&D activities within the area of interest, namely enhancing adaptive capacity. A desirable framework would indicate both the overall scope of the area and map the knowledge gaps within the area. An example of a suitable framework, proposed by Prof Coleen Vogel in consultation with colleagues, is presented below. The National Disaster Management Act and associated strategies can also provide useful insight in this regard.

Social resilience	• Social networks and social capital • Human behaviour (including education and other advocacy outreach) • Institutions (formal and informal e.g. government and wider civic society). This would also include legal systems and regulations • Vulnerability assessments.
Economic resilience	• Equity • Diversification of livelihoods • Technology (e.g. Early Warning systems; rainwater harvesting etc.) • Infrastructure (local and bulk, infrastructural development and monitoring).
Natural resilience	• Water resource management • Water conservation efforts e.g. demand management, Working for Water • Effective baseline and data monitoring of natural systems (e.g. SAEON), including surface water, ground water and water-linked ecosystems • Soil conservation measures.

Adapted from Rockstrom 2003 and the Africa Chapter, IPCC, Working Group II.

Prioritisation

The list of 13 suggested research topics was considered and, with a roughly conceptualized prioritisation framework in mind, consensus was sought on high-priority topics that identify themselves on the basis of importance and urgency. The result of this exercise resulted in the following:

Priority 1:

R&D in partnership with DWAF, to enable DWAF and CMAs to develop an integrated climate change adaptation response strategy, thereby mainstreaming adaptation within water resource management, nationally and regionally. This would also inform the next revision of the National Water Resource Strategy (NWRS), which is committed to addressing climate-change issues more adequately than has been possible in previous versions of the NWRS.

Urgency:	Very high
Time Frame:	1-2 years
Lead Sector:	Water sector
Collaborators:	Various sectors having a stake in water

Note: A project with potential commonalities “Using catchment climate scenarios to support adaptive learning within CMAs and WUAs”, to be undertaken by DWAF in collaboration with UCT, the Stockholm Environment Institute and Environment Agency (England and Wales), is due to commence in 2008.

Priority 2:

The development of integrated tools and measures to assess the effectiveness and efficiency of adaptation measures. Research should assist in designing tools that demonstrate the integrated social, environmental and economic benefit and cost-effectiveness of adaptation and to develop success indicators for adaptation measures, preferably within the context of carefully chosen, socially relevant case studies.

Urgency:	High
Time Frame:	2-3 years
Lead Sector:	Any interested sector, possibly DST (topic highly cross-cutting)
Collaborators:	Water and other stakeholder sectors; partners with expertise in the economics-related components are crucial

Priority 3:

Development of adaptive management capacity with regard to water-linked ecosystems based on a growing understanding the effects of climate change on ecosystem biodiversity as well as on ecosystem goods and services

Urgency:	High
Time Frame:	2-3 years
Lead Sector:	Water sector
Collaborators:	SANBI and others

Priority 4:

Development of comprehensive databases to assist in monitoring responses to the impacts of climate variability and change (also to the occurrence of extreme events) as they affect effectiveness, efficiency and shifting patterns of water use, thus enabling developing imbalances and vulnerabilities to be detected at an early stage and necessary adaptations to water utilization plans to be made.

Urgency:	Medium
Time Frame:	2-3 years
Lead Sector:	Water sector
Collaborators:	Water use sectors

Area 3: R&D Related to Delivering Adaptation Actions

Three potential research projects of high priority were identified:

Priority 1:

Mainstreaming climate change into water institutional arrangements; policies, strategies, pricing, governance, etc.:

a) the NWRS
b) CMPs (as well IDPs and WSDPs)

Points to consider when developing terms of reference:

- A project with potential commonalities "Using catchment climate scenarios to support adaptive learning within CMAs and WUAs", to be undertaken by DWAF in collaboration with UCT, the Stockholm Environment Institute and Environment Agency (England and Wales), is due to commence in 2008.

Urgency:	a) immediate, to facilitate input into revision of the NWRS due in 2009; b) medium term
Time frame:	Not indicated
Capacity constraints:	Not indicated
Partnerships:	Not indicated

Priority 2:

Piloting adaptation to the socio-economic impacts climate change has on vulnerable groups

Points to consider when developing terms of reference:

- Following the lead of, among others, the SEI and looking at groups, especially poor and vulnerable communities, through a livelihoods lens would enable the linkages between poverty and water to be explored. This is critical in a climate change context where issues of health, jobs, agriculture, etc., are explored holistically in order to find responses that are not maladaptive.

- Pilot areas need to include a coastal municipality (e.g. Durban)

Urgency:	Not indicated
Timeframe:	Not indicated
Capacity constraints:	Not indicated
Partnerships:	Not indicated

Priority 3:

Piloting rainfall enhancement technology to confirm its viability as an option to offset climate change impacts

Points to consider when developing terms of reference:

Urgency:	Not indicated
Timeframe:	Not indicated
Capacity constraints:	Not indicated
Partnerships:	Not indicated

General comment

- With regard to capacity requirements, it was recommended that the WRC should proactively engage with NRF and other responsible institutions to (i) promote the establishment of a Chair in Climate Change and encourage NRF to focus on bursaries for Climate Change studies and (ii) ensure that curricula are adapted to be climate-change sensitive.
- International cooperation is crucial and should be encouraged (DEAT is currently organising an exchange tour to Australia with which the WRC should link up to open up avenues for future collaboration).

Area 4: R&D Related to Mitigation

General comments by workshop participants

- As indicated in Sections of this document, the water sector is clearly a stakeholder in R&D performed in the interests of climate-change mitigation by other sectors.
- Close R&D partnerships are called for in some priority areas, e.g. in quantifying the correlation between energy and water use efficiencies, water sector partnership with the energy sector is clearly appropriate.
- With relatively few exceptions, the water sector will generally not be responsible for taking the lead in mitigation-related R&D.
- The water sector, and the WRC in particular, needs to forge strong relationships with various stakeholder sectors and organizations (e.g. Eskom, Sasol, DME, Nedlac and others) associated with mitigation projects, in order to sensitise them regarding the need for water-sector involvement and to clarify where common interests and mutual responsibilities lie.
- Under the current circumstances, the workshop participants did not consider it justifiable for the water sector to prioritise and initiate mitigation-related R&D projects.

6 General Recommendations

Building and developing capacity to perform research and implement research results

Capacity of potential researchers and implementing agents needs to be developed and nurtured on an ongoing basis. Current initiatives brought to the attention of the workshop, such as the exchange of experts among universities to ensure the best quality instruction, as well as engaging with NRF and other appropriate institutions to ensure adequate and appropriate support for students and instructors, as suggested by workshop, should be facilitated as far as possible by the water sector. Using research projects in the water-sector portfolio as vehicles for such facilitation would continue to make an important contribution to capacity development.

Partnership research

Priorities allocated by the workshop underline the fact that there are still crucial knowledge gaps that relate to climate-change impacts on water resources and utilization, which are primarily the responsibility of the water sector to address. While the water sector would clearly need to take the lead in R&D required to fill such gaps, representatives of sectors that are secondarily impacted through the primary CC impacts on water should, where appropriate, be invited to join as partners in such research. Equally, the water sector should make room for partnering other sectors (energy, industry, mines, health, etc.) in performing R&D where water is a crucial factor, albeit not the main issue. In research projects which seek to pilot adaptation measures and enhance resilience of vulnerable systems (e.g. communities, regions, ecosystems), the water sector has a crucial role (which may or may not be a leadership role) in cross-disciplinary partnerships.

International partnerships, as already clear from current R&D success stories, will continue to play a crucial role in the immediate contribution of (apart from funds) skills and insights, which may otherwise take a long time to acquire.

Economics approach

An economics-related research component will allow focus on the benefits and costs of different climate-change mitigation and adaptation strategies (incorporating policies, plans, projects, etc.) with a view to achieving a predefined objective, such as maximising social welfare. The whole research area of adaptation and mitigation should therefore be subjected to intense economic analysis wherever possible.

Stakeholders in climate change-related, water R&D investments

Because issues of water availability and utilization are so widely crosscutting, stakeholders in climate change-related water research cover a relatively vast area. Although there has been wide consultation in the process of developing an R&D portfolio as a water-sector responsibility, it emerges that certain stakeholders have been either under-represented or altogether missing, such as

- Scientists in the water policy and hydropolitical arenas (e.g. P Ashton, A Turton)

- Industry and mining (e.g. Sasol, Chamber of Mines)
- Business fora (Nedlac)
- Local government and officials

The need to remedy this prior to the conclusion of the process is recognized.

Provision for periodic revision of R&D portfolio

Because knowledge concerning climate-change and related issues is being gained and applied at a rapid rate internationally, it can be foreseen that R&D needs will change continuously. To remain relevant, a portfolio setting out a programme of prioritized research projects over a specified term may have to be revised periodically, even prior to end of the term.