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World Water Assessment Programme

UN WATER

Briefing Note

Water and Climate Dialogue

Adapting to Climate Change: Why We Need Broader and 'Out-of-the-Box' Approaches

The challenge of securing safe and plentiful water for all is one of the most daunting challenges faced by the world today. ...

Shortages of water contribute to poverty. They cause social hardship and impede development. They create tensions in conflict prone regions. Too often, where we need water we find guns ...

Ban Ki-moon, 2008

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Water is the primary medium through which climate change influences the Earth's ecosystems and therefore people's livelihoods and well-being.

Water-related climate change impacts are already being experienced in some river basins in the form of more severe and more frequent droughts and floods. Higher average temperatures and changes in precipitation and other climatic variables are projected to affect the availability of water resources through changes in rainfall distributions, soil moisture, glaciers and ice/snow melt, and river and groundwater recharge and flows. These factors are expected to lead to further deterioration of water quality as well.

The poor, who are the most vulnerable, are also likely to be affected the most (UN-Water, 2009).

Key messages

- There is evidence that the global climate is changing and that some of the change is human-induced.
- As stated by the Intergovernmental Panel on Climate Change (IPCC) in 2001, 'climate change impacts will be differently distributed among different regions, generations, age, classes, income groups, occupations and genders' (McCarthy *et al.*, 2001).
- Climate change will be a fundamental driver of changes in water resources. Furthermore, the hydrological cycle will be the main medium through which the impacts of climate change will be felt. The sustainable management of water must be a priority.
- While climate change will create further serious pressures on water supply, it is currently not the only, or the main, source of stress. The most important drivers are forces and processes generated by human activities, such as rising populations and the increasing demands for water and water-dependent products that come with rising per capita incomes.
- The consequences of these demographic and income-related effects are being felt in critical, water-dependent, economic sectors. The world is facing global crises in energy and food. These cannot adequately be addressed without considering the key role of water resources and their effective management.
- Public policy has so far been dominated by mitigation of climate change, but there needs to be a better balance between mitigation and adaptation. The World Bank (2010) has estimated the annual cost of adaptation to a 2 degree warmer world up to 2050 to be US$75–100 billion, of which 70 per cent is water-related.
- At a 2007 United Nations (UN) Security Council discussion on climate change impacts, UN Secretary-General Ban Ki-moon noted that climate change has implications for peace and security as well as serious environmental, social and economic implications, especially in 'vulnerable regions that face multiple stresses at the same time'.
- Adapting to climate change is a critical challenge, particularly for developing countries, whose capacity to adapt is low. For some, the incremental costs of climate change adaptation will soon approach the current value of aid inflows.
- Governments must give priority to water resources management in their adaptation policies. The impacts of climate change on water resources and services should be factored into development planning at regional, national and local scales and in all water-dependent sectors.
- Adaptation programmes for water should prioritize no-regret or low-regret measures, namely those which create benefits both with and without a climate change scenario. Particularly important are measures to protect and secure the resilience of ecosystems, and their sustainable use by humans.
- Groundwater is the major source of water across much of the world and it is likely to play an even greater role in human development under changing climatic conditions.
- Lateral 'out-of-the-box' thinking is essential for both decision-makers with a direct responsibility for the management of water and for all others whose decisions have a major impact on water resources and their management.
- While the world is taking steps to respond to the impacts of future climate change, little is being done to act on the water crises we are already experiencing.

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Section 1: Scientific basis

Introduction

The world is right to be concerned about climate change, which poses major threats to humans and ecosystems. The 2007 United Nations Climate Change Conference in Bali acknowledged that even the minimum predicted shifts in climate for the twenty-first century – more than twice the 0.6 °C increase that has occurred since 1900 – would be significant and disruptive (UN-Water, 2009).

The intergovernmental response has focused primarily on mitigation of climate change, embracing wide-ranging measures that include reducing greenhouse gas emissions, disseminating clean technologies and protecting forests. These measures may slow climate change and mitigate, to some extent, its adverse effects. However, they will not halt it or reverse changes already under way. Additionally, their impacts will often only be felt in the long term; it may take two generations before these measures have full effect. Even if successful, these measures imply a considerably changed future climate and some impacts that are unavoidable. These impacts include increasing water stress, more extreme weather events, higher levels of migration and the disruption of international markets.

Climate models show that the probability of extremes of rainfall is likely to increase, resulting in more floods and droughts in regions already affected by these kind of events – often these are regions with low income levels per capita, widespread poverty, high population growth and rapid urbanization. If climate change brings significant shifts in the availability of water resources, patterns of human migration are likely to be affected. In the meantime, people must be protected from the consequences of global climate change through adaptation measures. Adaptation, as embodied in the Nairobi Work Programme of the United Nations Framework Convention on Climate Change (UNFCCC), is based on gaining a better understanding of the impacts of climate change and making informed decisions about practical responses.

Current situation

Climate change will directly affect the hydrological cycle and, through it, the quantity and quality of water resources. Acting as a buffer between excessive availability of water (floods) and increased water needs (drought), groundwater is expected to play a key role in adaptation to climate change. As groundwater is the world's largest available source of freshwater and the primary source of drinking water for nearly half of the world's population, the importance of groundwater in a changing climate cannot be understated.

While the majority of governments appear aware of the need to respond to the future impacts of climate change, they are insufficiently motivated to act on the water crises that are already being experienced. Future impacts of climate change aside, development is threatened in many regions by factors that are not being adequately addressed, as clearly pointed out in the Intergovernmental Panel on Climate Change's April 2008 report on water (Box 1).

Given the complexity of the situation at hand, the third edition of the *World Water Development Report* (WWDR3; WWAP, 2009*a*) makes a strong plea for all decision-makers to transcend their normal working boundaries in order to consider the wider ramifications of water and the forces affecting it. Under changing climatic conditions, it is of prime importance to assess and reduce water-related risks and vulnerabilities in fields such as agriculture, energy, health, environment, and urban water utilities as part of overall development planning, especially given the magnitude of current uncertainties about the nature, exent and timing of climate change impacts. Agricultural production practices must adapt to cope with climate change. Hydropower production must be climate-proofed. Livelihoods and vulnerable societies and economies (both coastal and urban) must be adequately protected against water-related hazards and changed water quality and availability.

Box 1. Shortcomings of water management practices

Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope with current climate variability, hence large flood and drought damages occur. As a first step, improved incorporation of information about current climate variability into water-related management would assist adaptation to longer-term climate change impacts.

Climatic and non-climatic factors, such as growth of population and damage potential, would exacerbate problems in the future.

Source: Bates *et al.* (2008).

Public policy in response to climate change has so far been dominated by the need for mitigation. However, WWDR3 argues for a more judicious balance between mitigation and adaptation. Because some of the most serious climate change impacts are the affects on water and its various uses, adaptation is a vital component of water policy, just as water is an important aspect of mitigation. Water resource issues must therefore be prominent in climate change negotiations. Governments should commit themselves to providing the necessary degree of support, including finance, for adaptation measures. These issues are discussed in the second part of this briefing note.

Cost of climate change, risks and possible futures

Social considerations

In Africa alone, between 75 million and 250 million people may be exposed to increased water stress by 2020 due to climate change. Increased water demand is likely to intensify water-related problems.

While the impacts of climate change are predominantly felt locally, the forces at work are global in scale; the aggregate result of the behaviour of all countries. Responding to these forces will require international cooperation and coordination, as well as careful decisions and actions at the national level.

At a 2007 UN Security Council discussion on climate change impacts, UN Secretary-General Ban Ki-moon noted that climate change has implications for peace and security, as well as serious environmental, social and economic implications, especially in vulnerable regions that face multiple stresses at the same time, such as weak institutions, pre-existing conflicts, poverty and unequal access to resources, food insecurity, and high incidence of diseases such as HIV/AIDS. Furthermore, he outlined 'alarming, though not alarmist' scenarios, including limited or threatened access to energy increasing the risk of conflict, a scarcity of food and water transforming peaceful competition into violence, and floods and droughts sparking massive human migrations, polarizing societies and weakening the ability of countries to resolve conflicts peacefully.

As the effects of climate change and its adverse water impacts increase – often in politically charged areas – conflicts are likely to intensify, requiring new and rapid adaptive security strategies. Sudden changes in hydrological conditions that may occur as a result of climate change amplify the risk of major national and international security threats, especially in unstable areas. Adverse changes in internal, inter-jurisdictional and transboundary waters can put food, social, health, economic, political and military security at risk.

Current IPCC projections of rising temperatures and sea levels, and increased intensity of droughts and storms, suggest that substantial migration will take place within the next 30–50 years, particularly from coastal zones.

Gender-related considerations

Climate change impacts are not gender-neutral. Factors such as gendered divisions of labour, differences in access to and control of natural resources, different knowledge and skills, and different levels of participation in decision- and policy-making expose women and men to specific and different risks and opportunities. (The Gender and Climate Forum held in Geneva as part of the 2009 World Climate Conference-3 addressed these and related issues.)

In many contexts, women are more vulnerable than men to the effects of climate change. Historic disadvantages that women often still face – such as limited access to resources, restricted rights and a muted voice in shaping decisions – can make them especially susceptible to many impacts of climate change. The United Nations Development Fund for Women has published the following facts and figures (UNIFEM, n.d.).

- In Africa, the proportion of women affected by climate-related crop changes could range from 73 per cent in the Congo to 48 per cent in Burkina Faso.
- Gathering and transporting water typically falls to women and children in developing countries. This seriously limits their available time for education or other economic and political activities. Collecting water is expected to become increasingly burdensome with global warming.
- Shortages of firewood or other bio-fuels due to floods or drought, which are expected to increase with higher temperatures, add to women's workloads where they are responsible for its collection. Worldwide, girls already make up the majority of children who do not attend school.
- In hurricanes and floods it is a well-attested fact that women have a higher death rate than men, due to social inhibitions, lack of survival skills, and the fact that they often care for children, the sick and the elderly and may place themselves at higher risk to do so.

Economic considerations

The wide variation in estimates of the costs of climate change is due to different assumptions about future greenhouse gas emissions, mitigation measures, anthropogenic climate change itself, and how effectively countries will adapt to it. With these qualifications, the scale of economic impact is illustrated below:

- An estimated 40 per cent of development investments are currently at risk, according to analyses by the Organisation for Economic Co-operation and Development (OECD). These analyses indicate that while many development efforts contribute to reducing vulnerability to climate variability and change, climate risks are seldom explicitly factored into development projects and programmes.
- The Stern Review in 2006 concluded that by 2050, extreme weather could reduce global gross domestic product (GDP) by 1 per cent and that, unabated, climate change could cost at least 5 per cent of global GDP each year. If even more dramatic predictions eventuate, the cost could rise to more than 20 per cent of GDP.

The costs of adaptation have been estimated as follows:

- The World Bank estimates that the additional costs to adapt or climate-proof infrastructure range from US$9 billion to US$41 billion per year. A recent update by the United Nations Development Programme (UNDP) predicted that the mid-range of the costs of adaptation will be about US$37 billion per year in 2015.
- The UNFCCC estimates that the additional investments required to adapt to climate change are likely to cost between US$28 billion and US$67 billion per year several decades from now, potentially reaching as high as US$100 billion per year. The additional annual investment needed in water-supply infrastructure in 2030 is likely to be US$11 billion, 85 per cent of which will be needed in developing countries.

What is at stake?

Climate change is likely to present challenges in a number of key areas at a varying degree of intensity. (Section 2 will discuss what can be done and present relevant policy options.)

- *Drinking water supply and sanitation:* Existing water supply and sanitation infrastructure has been designed for different demands, resource availability and water use than those expected in the future. Such historical infrastructure will be placed under greater pressure as a result of hydraulic changes and warmer temperatures, as well as the increased demand linked to population growth, development and associated demographic and other changes. A recent study of water supply and sanitation services shows that many populations are not resilient to climate change impacts. Groundwater is the primary source of drinking water for nearly half of the world's population. In the light of climate change and an expected increase in the frequency of droughts, the importance of groundwater is likely to rise further (UN-Water, 2010).
- *Agriculture:* Climate change is expected to affect both rainfed and irrigated agriculture, including feed and fodder for livestock. Climate change will alter the distribution of agriculture across the globe, shifting the potential for agriculture to high latitude areas, whereas in low latitudes areas more frequent and severe droughts/dry spells and floods will hurt subsistence agriculture, in particular female farmers in semi-arid zones. This shift will worsen the living conditions of rural populations who live in fragile environments and depend on agriculture for their livelihoods. These communities face an immediate and increasing risk of crop failure or loss of livestock and loss of fertile topsoil owing to greater erosion. Currently 70 per cent of global groundwater abstraction is used in irrigation, with groundwater estimated to supply 30 per cent of the world's irrigated land. During extended droughts, the use of groundwater for irrigation is expected to increase, including more intensive use of non-renewable groundwater resources, which may not be sustainable (UN-Water, 2010).
- *Urban settlements:* Half the world's population is already settled in urban areas, and the majority of this urban population live within 100 km of the sea. The concentration of people in urban areas will increase further, with the largest increases expected in Africa and Asia. Urban areas will experience increases in the frequency and intensity of heavy rain, storms, droughts, heat-waves and other extreme weather events. The urban centres most at risk are those where these events are already widespread. The expected increase in frequency and intensity of weather extremes will further increase risks in these already threatened areas. Moreover, changes in mean temperatures, precipitation distributions and sea level will have an impact on energy demand, will reduce the draining capacity of sewage systems, and will increase long-term vulnerabilities of low-lying coastal cities. Another frightening, but not yet fully explored, implication of climate change relates to the possible effects of abrupt changes in temperature and weather patterns (Romero Lankao, 2008).

Climate change is expected to affect both rainfed and irrigated agriculture

Water-related hazards have become more frequent and intense in many regions. At the same time, demographic changes are exposing more people to increased occurrence of floods, cyclones and droughts, resulting in many deaths and costing billions of dollars in damages, thus deepening the poverty especially in developing countries.

- *Health:* Climate change will influence human health through various water-related impacts. Changes in the composition of aquatic ecosystems will have an impact on nutrition, exposure to health risks, and access to health services for communities whose livelihoods are closely linked to such ecosystems. In particular, the occurrence of opportunistic invaders, such as cyanobacteria in lakes and reservoirs, will pose new challenges for water service companies. There has been a resurgence of water-related vector-borne diseases in areas where eradication programmes had previously been successful, and emergence of new vector-borne diseases in areas where they were previously unknown. Although it is difficult to identify the driving forces behind these changes, climate change cannot be excluded. Reduced nutrition and access to safe water for human consumption and personal hygiene may compromise basic human health and, in particular, the health burden caused by diarrhoeal diseases will negatively affect the mainly female caregivers. Malnutrition owing to water shortages and limited safe drinking water during flooding may induce outbreaks of water-related diseases. New breeding places for mosquitoes and other disease-transmitting insects may also develop. Groundwater resources may also need better protection against contamination from extreme rainfall and floods (UN-Water, 2010).
- *Environment:* Services provided by ecosystems support livelihoods and economic development. The impacts of climate change on water will aggravate drivers of ecosystem degradation, thereby reducing the benefits obtained from these ecosystems, such as clean water supply, fisheries and coastal defences. The impacts of climate change on ecosystems will increase the vulnerability of communities (UN-Water, 2010).
- *Extreme weather events and poverty:* Water-related hazards have become more frequent and intense in many regions. At the same time, demographic changes are exposing more people to increased occurrence of floods, cyclones and droughts, resulting in many deaths and costing billions of dollars in damages, thus deepening the poverty especially in developing countries. This is an indication of what could lie ahead with increased climate variability. As an example, it has been estimated that inability to tackle hydrological variability in Ethiopia will bring about a 38 per cent decline in GDP and a projected 25 per cent increase in poverty over the period 2003–2015 (UN-Water, 2010).
- *Increased migration:* The direct supply-side effects of climate change – including increased water scarcity, flooding, accelerated glacial melting and rising sea levels – have the potential to significantly accelerate human migration. According to various estimates, between 24 million and almost 700 million people have already been displaced because of environmental changes over the past few decades, largely as a result of water-related factors. Such migration would seriously affect development projects designed to relieve future stresses on water availability.

What needs to be strengthened? A shortage of information, money and capacity

- *Information for decision making and planning:* Managing water resources is made more difficult by a lack of knowledge and information which is required for decision-making and long-term planning. Few countries know how much water they are currently using or for what purposes it is being used, nor are many details available about the quantity and quality of water resources available. The knowledge gaps are even larger when predicting future conditions. Few countries know how much water can be withdrawn without serious environmental consequences, nor the amount of finance being invested or needed in water management and infrastructure under future circumstances. Climate change, interacting with other drivers including population growth, land-use changes and urbanization, further complicates these uncertainties (WWAP, 2009*b*).
- *Financing:* Developing countries currently lack effective funding mechanisms to support adaptation to climate change where it is needed the most. As an example, in Africa the potential impact of climate change could include increased energy shortages, reduced agricultural production, worsening food security and malnutrition, spread of disease, humanitarian emergencies, growing migration and increased risk of conflict over scarce land and water resources. Yet many African countries are the least able to meet the costs of adapting to these challenges and receive far too little from current adaptation funds. The various costs of adaptation should be assessed at country and regional level and spending priorities established accordingly.
- *Capacity-building:* Greater institutional capacity and human capacity are needed, both within the water domain and outside it. Capacity development can occur through traditional forms of education, on-the-job training, e-learning, public awareness raising, knowledge management and professional networks (WWAP, 2009b). It is also essential to build the necessary research capacity in developing countries to reinforce local problem-solving capacity, for instance to tailor adaptation measures. Creating such an enabling environment might include, for instance, the development or encouragement of policies, legislation, norms, modes of operation or civic engagement across different parts of society.
- *Coordination:* Coordination among those sectors affected by climate change as a result of its effects on water resources will be crucial. Where countries already have integrated water resource management (IWRM) plans, adaptation plans need to be integrated with them. Where there are no IWRM plans, adaptation planners need to involve water managers in their decisions. Institutional arrangements need to be made to promote coordination and integration. There will need to be close linkages between ministries of environment, water, energy, agriculture, planning, health and others, reflected in national adaptation plans of action, poverty reduction strategy programmes, national sustainable development strategies and IWRM plans.

Developing countries currently lack effective funding mechanisms to support adaptation to climate change where it is needed the most

Section 2: Policy and response options

The challenges

Society will need to adapt to the changes that are expected and become more resilient and able to cope with outcomes that are still uncertain. Adaptation can have immediate benefits, as well as making society better prepared for greater extremes in terms of both water shortages and excesses. In many cases, investment in infrastructure is one vital measure – but there is also a need for improved management and better information for planning and decision-making. Reforms to the governance and financing of water resources will be essential. Changes will also be need to be made to the way water issues are tackled by policy-makers in key areas such as drinking water supply and sanitation, agriculture, energy and public health.

Keynotes of adaptation responses

Climate change could affect most aspects of social and economic life. All sectors of society should be prepared for these potential impacts. This section highlights some of the principal issues governing public responses to the challenges set out above, drawing on the recent work of UN-Water and WWAP: *Climate Change Adaptation: The Pivotal Role of Water* (UN-Water, 2010) and *The implications of Climate Change on Water* (WWAP, 2009c). The overriding theme of both publications is the need to 'mainstream' water adaptation in development policies (Figure 1).

Figure 1. Mainstreaming adaptation of water to climate change

Policy domain	Key factors
strategic planning	adaptive management
institutional reform	women's involvement
data and informatics	ethical responses
infrastructure	human capital
disaster policy	funding

The onset of climate change, and the fact that water is essential, creates a need for widespread changes in mindsets and mainstreaming of adaptation efforts throughout societies and economies. This is in part about overcoming a 'silo mentality' – by which water is considered in isolation from other economic, social and development issues – and about factoring water into key decisions to be made about adaptation. It is also about encouraging recognition of the importance of water in parts of society where it has not already recognized. Mainstreaming implies 'joined-up' thinking about the role water plays in tackling major global problems:

> Water is part of the vital nexus of climate change, energy, food, environmental degradation and economic and social development. Solutions for these major challenges (e.g. in the realms of bio-energy or food security), if conceived in isolation without considering their impact on water, can aggravate other issues and becoming self-defeating (WWAP, 2009c).

Policy implications

Mainstreaming adaptation involves strategic planning, institutional reform and revamping, investment in data collection and informatics, investment in the creation of new – and modification of existing – infrastructure, and greater attention to disaster preparedness and hazard management.

Planning on a strategic scale

The long lead times of adaptation processes means a strategic planning vision is required. Current examples are the planning exercises conducted for the Economics of Climate Adaptation Working Group and the 2030 Water Resources Group, which quantify, prioritise and set boundaries for water over a 20-plus year horizon, and the consideration that UN agencies are now giving to Green Economy implications for water and other economic sectors.

Water scarcity is likely to be aggravated by climate change in many regions. More countries will find it increasingly difficult to providing water to their growing, water-intensive cities, farmers and industries. Investments in measures to bring supply and demand into better alignment can safeguard future development in such cases. A case in point is South Africa, where concerns for future water security led the Department of Water Affairs and Forestry to create a Water for Growth and Development Framework, which now guides national policy on water (see also Box 2).

Water development is an integral part of the Green Economy agenda. In many arid countries, irrigated agriculture is by far the largest consumer of water (up to 80 or even 90 per cent of available supply). Consequently, a resilience strategy for water resources to cope with climate variability starts with demand management in agriculture. Pollution mitigation, wastewater treatment, energy efficiency, irrigation, hydropower, and the management of natural water ecosystems (including wetlands) are all critical aspects of the effective management of water.

Many of these projects are of the 'win–win' type, which target several objectives simultaneously, and this synergy should be helpful in the financing context (UNEP, 2011). By contrast, current food security policies, involving high subsidies and uneconomic pricing of water and power, act as perverse incentives in respect to the efficient management of water in the face of climate change.

Revamping institutions to make them 'fit for purpose'

In many societies, the development of institutions to govern and manage water lags behind the pace of change required. In Latin America and the Caribbean, for example, institutions that are able to deal with water allocation issues under conditions of scarcity and conflict have proved difficult to establish. Climate change will increase the pressure to adapt institutions to future challenges, for example by producing new national water policy frameworks or revising laws concerning water rights. Different countries adopt different institutional models for water – there is no universally accepted blueprint. Indeed, the co-existence of different institutional models could increase their resilience to climate change and increase potential for both policy and technological innovation.

Another example of an institutional response is promoting local adaptation actions within a national or regional strategic framework. Local actors and stakeholders play a key role in reducing vulnerability according to the subsidiarity principle. Local knowledge can have a large impact on risk reduction and should be promoted through an inclusive process of stakeholder consultations that involve women, basin-level organizations and other important groups.

The prospect of climate change is leading to more multi-sector and multi-disciplinary collaboration. This common threat requires water institutions and policies that are sufficiently flexible, adaptive and robust to deal with uncertain and changing water futures. This complicates the task of water managers, already faced with escalating demands, since past hydrological conditions are no longer a reliable predictor of the future. Unless institutions can accommodate such uncertainty and shift water to where it is needed most, climate change will be even more costly for water users and their communities.

Revolutionizing data and informatics

Climate change is affecting the water landscape in ways that are still not fully understood, as well as having an impact on other factors that interact with water. However, there is a scarcity of data on which to base planning and adaptation. The overriding issue at global and regional scales is to maintain and enhance observational networks that can track both climatic and hydrological data. Unfortunately, in some parts of the world the number of active, on-the-ground observation stations has been declining for several decades (for climatic data see Mitchell and Jones, 2005).[1]

Several remote-sensing technologies are available that can contribute to surface and groundwater monitoring activities, offering the advantages of global coverage, availability of data and metadata, error

Box 2. South Africa's future water imbalance

South Africa has a diverse and thriving economy, but its continuing political and social harmony depends on a continuation of high economic growth to meet the expectations of its citizens and to redress historical inequities. On current trajectories, and unchanged policies, its urban, agricultural and industrial growth projections to 2030 are incompatible with the country's water endowment.

In the base case scenario, South Africa faces a 17 per cent gap between projected 2030 demand and current supply equivalent. Even this assumes that agricultural water demand is capped at present levels. The impact of climate change might increase the size of this gap. Competition for limited water supplies will intensify in each of the basins feeding the largest cities – Johannesburg, Pretoria, Durban and Cape Town. Household demand is expected to increase from the growth of incomes and improved service coverage, while industry, power generation, mining and agriculture – the sectors that will drive the growth of incomes – are all water-intensive.

Closing the projected supply–demand gap for water in 2030, and thereby enabling South Africa's growth potential to be achieved, will depend on a portfolio of different measures: supply-side transfer schemes; new dams; better use of water in mining and industrial companies; modifications to existing structures; and re-engineering of existing irrigation schemes to make them more water efficient. In short, a balance of supply-side and demand management measures.

Source: 2030 Water Resources Group (2009).

1 The number of stations recording data from stream-flow gauges has also declined for some time, particularly in Africa.

statistics, and the ability to provide meaningful spatial averages.[2] Perhaps the most valuable remote-sensing technology for groundwater investigations is high-precision satellite gravimetry, which can be used to assess changes in groundwater storage at a regional scale.[3]

Much of the observational infrastructure for recording data on a global scale is owned and operated by governments. Setting up and operating large observational networks, including satellite launching and servicing, needs large budgets.[4] Though much of this will remain a public (and international) responsibility, the immense costs involved leave openings for private satellite operators too. The use of satellite observations on national and local scales for applied purposes is making rapid progress, involving both private companies and international public agencies. The following examples are cited from *The Economist* (2009, p. 89):

- *Infoterra* is the largest provider of satellite data for the analysis of farmland in France. The firm expects the amount of farmland monitored in this way to increase as a result of climate change, since farmers can no longer rely on the past as a guide to the future.
- *RapidEye*, a German satellite operator, sells data to insurance companies marketing crop-insurance policies to governments in countries at risk of drought and famine. The company has the capability of analysing the productivity of fields down to five-metre square patches.
- *The World Agroforestry Centre* in Nairobi is cataloguing the radiation signature – giving the agricultural potential – of 100,000 samples of African soils. The data is being passed on to the International Centre for Tropical Agriculture in Colombia to create a database, the Digital Soil Map.
- The *United States National Aeronautics and Space Administration (NASA)* in Washington and the *European Space Agency (ESA)* in Paris are major providers of public satellite information to a multitude of public and private sector users.

The importance of producing good hydrological data at a usable scale can be illustrated for West Africa, where a decrease of 20–40 per cent of rainfall has been observed at the height of the rainy season in July and August since 1970, and the onset

2 Landsat, Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Very High Resolution Radiometer (AVHRR) and other instruments can be used to infer a shallow water table. Landsat imagery can also provide geological clues where not obscured by vegetation. Altimetry measurements and synthetic aperture radars (SAR) over time can show where land subsidence is occurring, which is often an indicator of groundwater depletion. Microwave radar and radiometry measurements can be used to estimate snow and surface soil water, which further constrain groundwater assessments.

3 The NASA/German Gravity Recovery and Climate Experiment (GRACE), the first twin satellite gravimetry mission, is currently being used to generate time series of total terrestrial water variations (Tapley *et al.*, 2004)

4 Satellite imagery can in a number of cases compensate for the lack of ground monitoring. However, it is still far from being an adequate replacement. Observations are much better when satellite imagery can be combined with ground monitoring.

of the rainy season has become more variable (a greater 'coefficient of variation'). Rainfall variability is clearly observed and reinforced in the discharge time series of many rivers in the subregion, with the decrease of discharge recorded for many of the river basins concerned varying by 40–60 per cent. A clear link has been demonstrated between changes in ocean sea surface temperature and changes in average annual rainfall in the Sahel region.

Investing in infrastructure: No-regret and cost effective choices

Greater unpredictability, variability and extreme events will call for new water infrastructure and major modifications to existing structures. Coastal zones will be particularly affected. Subsectors include dams; reservoirs; irrigation; levees; coastal and inland flood protection; urban water supply and sanitation; wastewater treatment, disposal and re-use; pollution control; and ecosystem management, among others. Many of these projects will serve several aims at once ('win–win') and some of these will be justified even if climate change predictions prove to be unfounded ('no-regret'). Such projects should be prioritized within national investment programmes.

The IPCC has defined the no-regret criterion as a policy that would generate a net social and/or economic benefit irrespective of whether anthropogenic climate change occurs. No-regret policies are also more loosely referred to as win–win, or double dividend actions. Examples include demand management measures, improvements in the efficiency of water distribution, wastewater recycling, early warning systems for floods, droughts, and other extreme weather events, and risk spreading through insurance schemes. It may also include constructing new supply infrastructure, retro-fitting existing structures, altering operational protocols, and developing new water sources or water transfers. No-regret projects may be attractive on paper, but they still need active promotion – the climate-change scenario may provide the extra impetus they need.

Certain types of infrastructure are especially vulnerable to climate change and will particularly benefit from risk analysis and risk management. These include highly capitalized or unique projects, engineering structures with long lifetimes, multi-purpose infrastructure systems, projects with long-lived streams of benefits and costs, systems susceptible to climate anomalies or extreme events, and rural and urban water supplies.

Not all adaptation involves hardware and physical infrastructure: software and the adjustment of systems and services are key to many vital adaptation measures, including IWRM modelling, forecasting, and establishing protocols for river basin and transboundary management.

More resources for disaster preparedness and management of new hazards

Natural disasters aggravated by climate change – such as flooding, droughts, hurricanes, coastal damage – will call for more resources to be devoted to disaster prediction and preparedness. Although better infrastructure would relieve the problem in many cases, vulnerable populations cannot be fully protected. Protection against hazards can never be absolute. In certain circumstances, the most feasible form of adaptation may be to ensure that at-risk populations are adequately warned and prepared for hazards, and that social and financial safety nets exist to compensate and provide for them. Regions that are regularly plagued by droughts and flooding, such as north-east Brazil, have been highlighted as examples of situations likely to become more widespread as a result of climate change. Disaster preparedness and insurance should be part of the adaptation tool-kit.

Key factors for intervention

Adapting water to climate change will involve actions by stakeholders at different levels, which are further considered in the final section of this paper. A number of the key factors affecting these interventions are discussed below:

1. Adaptive water management practices

2. Ethical considerations

3. Engaging women in adaptation

4. Human capital development

5. Funding to support adaptation

1. Adaptive water management practices

Adaptive water management requires resilience in management at all levels. In response to the risks and uncertainties of climate change, water management needs to adapt to events and trends as they unfold. This is a potentially large and varied agenda:

> The US Army Corps of Engineers has interpreted adaptive water management pragmatically to include a raft of separate measures, including: risk-based planning and design of infrastructure to account for climate uncertainties; development of a new generation of risk-based design standards for infrastructure, responding to extreme events; life-cycle management of aging infrastructure; vulnerability assessment of water infrastructure; improved forecasting methods for improving reservoir and emergency operations; strengthening of inter-agency collaboration; etc. (Stakhiv and Pietrowsky, 2008).

Greater climate variability and fundamental uncertainty would have profound implications for decisions about water infrastructure, which typically has a long physical life. These implications are at various levels, and of different kinds:

- The *climate risk* of such infrastructure should be assessed, at a sector and/or project level.[5]

5 Economics of Climate Adaptation Working Group (2009) contains cases studies at the regional level. MWH Americas Inc. (2009) contains cases studies of multi-purpose water infrastructure projects.

- Traditional ways of dealing with risk in *cost–benefit analysis* need to be fully exploited – these methods include sensitivity analysis, switching values and risk-benefit analysis.[6]
- Decision rules should be used that take into account the *risk preferences* of the agency concerned (such as minimax, maximin and minimum regret).[7]
- These traditional aids to decision-making under uncertainty and risk need to be complemented by the use of *scenario building*, which constructs plausible futures that could not necessarily have been predicted by extrapolation from current trends. Projects that stand up well in different scenarios are considered to be *robust*.
- *Project design* needs to allow for greater climatic variability and be *resilient* in dealing with events that cannot yet be foreseen. The initial cost of incorporating resilience – such as increasing storage, which may not be needed, or forfeiting current economies of scale in favour of greater freedom to manoeuvre in the future – could be regarded as an insurance premium to avoid future losses in the climate change scenario.

2. Ethical considerations

Ethics is not a separate issue or a separate area of policy development. Rather, principles derived from environmental ethics can help clarify the nature of water-related challenges of climate change and provide criteria against which to select appropriate policy responses. The contribution of environmental ethics is not an optional add-on in this regard, but rather a necessary consequence of the key features of climate change.

Climate change is inherently a knowledge-based problem. It exists only through the scientifically generated models that compare real situations to counterfactual alternatives and that map out possible futures. How scientific knowledge is produced and shared is thus both an ethical and a practical concern. From an ethical perspective, three issues appear significant in this regard:

- *Integrity:* the collective institutions of science need to ensure that scientific knowledge is assessed by internal standards of rigour rather than by external standards of relevance or convenience; in addition, communication of scientific knowledge needs correctly to reflect uncertainties and knowledge gaps.
- *Pluralization of knowledge:* formal science is not the only source of relevant knowledge – local, traditional and indigenous knowledge constitute an invaluable complement, particularly in areas where there are major gaps in observing systems or modelling capacities.
- *Orientation of knowledge to human needs:* it is a matter of ethical concern that the most serious gaps in scientific knowledge tend to concern possible climate change impacts on the most vulnerable people.

Furthermore, mitigating or adapting to possible climate change, the detailed impacts of which are inherently uncertain, is essentially a matter of assigning responsibilities, which in practice is a legal and political matter. However, reflecting on the grounds of responsibility is an issue for ethics. Any public debate that calls on notions such as 'fairness', 'equity', 'solidarity' or 'frugality' is an ethical debate – even if it does not fully recognize it. Addressing the heightened water stresses likely to be caused by climate change demands a responsible approach both to water use and to water policies. What counts as 'responsible' in this regard cannot simply be read off from past experience or inherited moral codes. In the face of climate change, new thinking is required on key issues such as needs, solidarity and inter-generational equity.

Finally, thinking about responsibility in the context of uncertain knowledge raises questions of value that fall squarely within the province of ethics. It is to be expected that, at least in some circumstances and scenarios, coping with climate change will require making difficult choices – among alternative water uses, among the needs of various populations, between present and future generations, and between humans and non-humans. The choices made will reflect values, whether or not they are made explicit. An ethical approach can assist in clarifying the values at stake in particular policy options and, at least in favourable circumstances, in establishing a shared framework of values that can help to manage conflict.

6 Sensitivity analysis measures the impact of a change in a specific variable on the project's rate of return. Switching values are the change in a specific variable required to reduce the rate of return to zero. Risk-benefit analysis compares the risk of action (= its cost) with the benefit of action (= avoided loss).

7 Minimax = minimizing the maximum expected loss; maximin = maximizing the minimum likely outcome; minimum regret = minimizing the difference between the worst possible outcome and others.

3. Engaging women in adaptation

In addition to their voices as citizens, in many societies women play key roles in how water is used – as producers (farmers, business people, service providers, artisans, etc.) and frequently as household managers. The ability of women to adapt to climate change depends on factors such as their economic power (control over land and property, money, credit and tools), family situation, health, personal mobility, household entitlements, food security, safe housing and personal security. In terms of these factors, women in many regions are less able to adapt to climate change than men: they represent the majority of low-income earners, they often have had less access to education than men, and they are less likely to be reached by extension agents.

Women may also lack rights to property and land, which could restrict their access to credit and agricultural extension services. It is often assumed that men are the farmers and, as a result, new agricultural technologies – including the replacement of plant types and animal breeds with new varieties intended for higher drought or heat tolerance – may not be targeted to women farmers (DFID, 2008).

The knowledge and experience that women offer relevant to coping with climate change impacts should be valued and tapped. Where women will likely be the main agents of adaptation, their incentives and constraints must be addressed head-on.

4. Human capital development

Climate change adaptation makes it urgent to reverse the loss of key human capacity in many countries. Administrations and professional cadres in many developing countries are not geared up to implement the adaptation agenda. In many cases they are actually losing capacity as experienced people retire or leave public service. This loss of human capacity argues for reviewing the functions and human resources of public servants, and their technical advisers, in the face of the challenges likely to be posed by climate change. The need to review the training needs of local water practitioners is especially great, considering the skill-sets they will require (Box 3).

5. Funding to support adaptation

Adaptation projects implemented by public agencies can draw on a range of development funds, including new adaptation funds created for this specific purpose. However, much of the adaptation/mitigation effort will fall to private companies, farmers and households, as well as sub-sovereign agencies who cannot tap into such funds. For them, commercial financial sources are critical. The *Report of the Secretary-General's High-level Advisory Group on Climate Change Financing,* published on 5 November 2010 (UN, 2010), presents a number of adaptation funding proposals.

Public agencies have access to specialized climate change funds, a number of which are available for adaptation in water. These include the Adaptation Fund, a financial instrument established under the UNFCCC and its Kyoto Protocol to finance concrete adaptation projects in developing countries. The Adaptation Fund is financed with a 2 per cent share of certified emission

Box 3. Skill-sets for local water practitioners

In order to be fully effective, local water supply and sanitation (WSS) and water, sanitation and hygiene (WaSH) managers and workers should have the following competencies (among others):

- Understanding of national and local budgeting, and how to present funding applications
- Familiarity with basic elements of accounting, financial management, stock control and personnel management
- Presentation of project proposals to external donors and non-governmental organizations, with their own specific requirements
- Management of stakeholder consultation exercises and processes
- Knowledge about the conduct of surveys of potential users and customers to determine their needs and preferences
- Ability to engage policy-makers in other water-related areas, especially in agriculture, health, education industry, etc.
- Awareness of what local private businesses can bring to service delivery, what their potential contributions are, and how can they be managed, contracted and regulated

Source: Winpenny (2009).

reductions issued for clean development mechanism projects, as well as through voluntary pledges from donor governments. Another relevant fund is the Pilot Program for Climate Resilience (PPCR), sponsored by the World Bank and other major international financial institutions, that enables developing countries to better integrate climate resilience into national and sectoral development plans.

UN-Water (2010) explains the need for funding in the following terms:

> The cost of inaction and the economic and social benefits of adaptation require increased and innovative investment and financing. Improving adaptive capacity calls for more intelligent use of existing financing, targeted towards the most vulnerable groups. The full range of financing options needs to be used, including innovative financing mechanisms, private sources and public funding from developed countries.
>
> Developing countries currently lack effective funding mechanisms to support adaptation to climate change. More funding must be made available for adaptation strategies to become sustainable. Increased support is needed for adaptation actions through targeted financing and improved aid effectiveness. As such, any adaptation funding must be new and must supplement Official Development Assistance (ODA) funds, in view of the compensatory nature of such funds. All sectors concerned should have access to existing funds to improve their adaptation strategies. Sound land and water management practices that provide mitigation and adaptation benefits should be eligible for such funding. Climate change adaptation should be integrated into existing funding for water management, and adaptive water management should be considered a funding priority for other water-reliant sectors.
>
> Development budgets are already under high pressure as a result of the global economic crisis. Future financing mechanisms are needed to generate sufficient resources and deliver them in a less complex manner, supporting the integration of adaptation concerns into the broader development agenda.

A different kind of finance is required for adaptation/mitigation carried out by commercial entities (including farmers) or other water users. According to one estimate, private investment is currently by far the largest source of climate finance in developing countries, contributing US$57 billion annually, compared with US$12 billion from governments and US$1 billion to US$3 billion from carbon markets (*The Economist*, 2009).

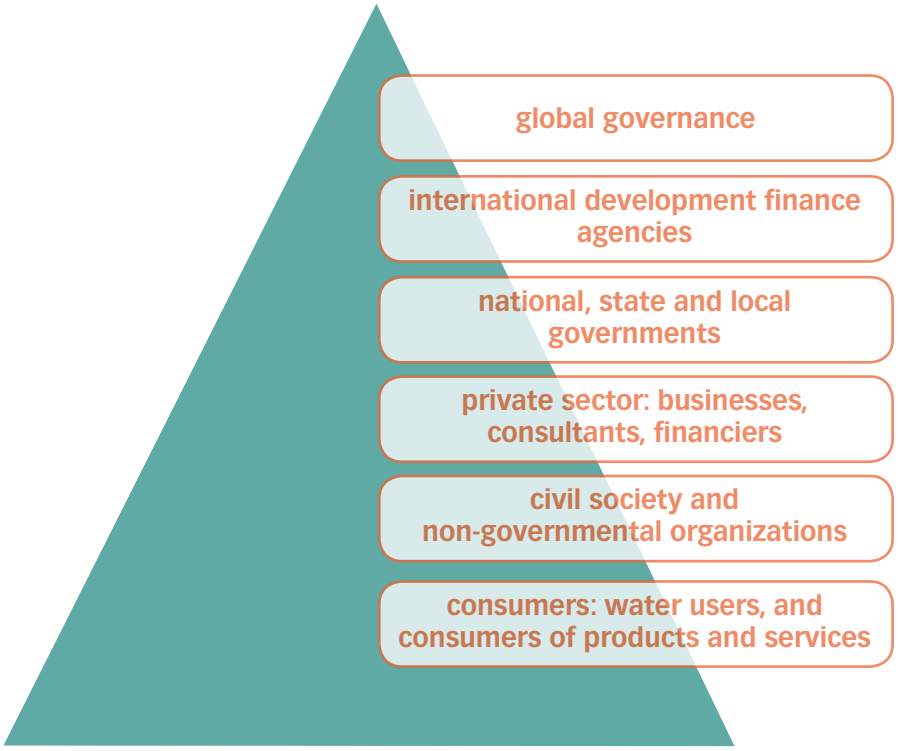


Figure 2. Hierarchy of stakeholders involved in water adaptation

Actions for stakeholders

The adaptation agenda demands a response from stakeholders at all levels (Figure 2)

1. Institutions of global and regional governance and international processes and initiatives

- The impact of climate change on water needs to be on the mainstream agendas of all relevant agencies and processes, starting with the UNFCCC.
- Initiatives to promote particular causes and sectors (MDGs, biofuels, global food security, etc.) should take full account of their implications for water use.
- International and regional systems of water governance (e.g. transboundary international water agreements) need more nurturing and financial support. This applies particularly to data collection, monitoring and analysis.

2. International development finance agencies (including The World Bank, regional development banks, the European Investment Bank and the European Union) and bilateral aid agencies

- Resources, operating modalities and lending policies should be adequate for the new challenges.
- Adaptation should become as mainstream as possible in regards to lending, although initially some policy and institutional overlays may be desirable.

3. National, state and local governments will set the rules of the game to make adaptation happen

- National, state and local governments will have key roles as advocates, educators, legislators, policy-makers, regulators, implementers, funders, partners and enforcers.
- Strategic planning, institutional development and policy review needs to be carried out urgently at an appropriately high level, cascading down the administrative hierarchy.
- An array of market signals and non-market inducements and sanctions will need to be introduced to change public mindsets about the use of water.
- National, state and local governments will set the rules of the game to make adaptation happen. If plans are not 'water smart', government leaders should not accept them.
- The coordination of cross-sectoral efforts is critical.

4. Private sector (businesses, consultants, financiers)

- Within the strategic, policy and regulatory frameworks set by governments, market players will shoulder much of the responsibility for implementation – as producers, financiers, and providers of technology and expertise.
- As producers and equity investors, the private sector can lead the way in developing products and services appropriate to the markets that will in a climate change era and in providing financial services tailored to support adaptation.
- As specialist suppliers of technical know-how and consultancy expertise, the private sector can introduce the knowledge and skills required to accelerate adaptation throughout the economy.

5. Civil society organizations (including non-governmental organizations)

- Local, national and international groups and non-governmental organizations can provide a bridge between governments and citizens, offering two-way communication of messages and concerns.
- Awareness of water adaptation can be spread throughout society through education and advocacy, and holding governments to account.
- Environmental champions can vocalize the needs of natural ecosystems.
- These organizations can provide independent scrutiny of adaptation efforts undertaken by public and private parties.

6. Water users and product consumers (households, farmers, etc.)

- Water users should adjust their water conservation and protection behaviour to growing water stress.
- Consumers should understand the implications for water of the consumption of specific goods and services (e.g. food, electricity, recreation services).
- Dialogue and advocacy about responses for consumption patterns, manufacturing processes, trade, etc. is required.

In short, the adaptation of water to climate change is everybody's business. We are all stakeholders.

References

2030 Water Resources Group. 2009. *Charting our Water Future: Economic Frameworks to Inform Decision-Making.* 2030 Water Resources Group.

Ban Ki-moon. 2008. Address by the United Nations Secretary-General to the session 'Time Is Running Out of Water' of the Davos World Economic Forum, Davos, Switzerland, 24 January 2008.

Bates, B. *et al.* (eds) 2008. *Climate Change and Water.* IPCC Technical Paper VI. Geneva, Intergovernmental Panel on Climate Change (IPCC) Secretariat.

DFID (Department for International Development). 2008. *Gender and Climate Change: Mapping the Linkages.* London, DFID. Available from http://www.bridge.ids.ac.uk/reports/Climate_Change_DFID.pdf

Economics of Climate Adaptation Working Group. 2009. *Shaping Climate-Resilient Development: A Framework for Decision-Making.* Available from http://www.mckinsey.com/App_Media/Images/Page_Images/Offices/SocialSector/PDF/ECA_Shaping_Climate%20Resilent_Development.pdf

The Economist. 2009. Agriculture and satellites: Artificial satellites are helping farmers boost crop yields. *The Economist*, 5 November 2009, p. 89.

McCarthy, J. J. *et al.* (eds) 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability Contribution of the Working Group 2 to the Third Assessment Report of the IPCC*. Cambridge, Cambridge University Press.

Mitchell, T. D. and Jones, P. D. 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology*, Vol. 25, No. 6, pp. 693–712.

MWH Americas Inc. 2009. *Water and Climate Change: Assessment of Climate Change Impacts on Multi-Purpose Water Infrastructure.* Report prepared for the World Bank.

Romero Lankao, P. 2008. *Cities and Climate Change: Review of Current Issues and Trends.* Draft report prepared for the UN-HABITAT *Global Report on Human Settlements 2011*, Nairobi, UN-HABITAT.

Stakhiv, E. Z. and Pietrowsky, R. A. 2008. *Adapting to Climate Change in Water Resources and Water Services.* US Army Corps of Engineers (USACE) Institute for Water Resources. Washington, DC, USACE.

Tapley, B. D., Bettadpur, S., Ries, J. C., Thompson, P. F. and Watkins, M. M. 2004. GRACE measurements of mass variability in the Earth system. *Science*, Vol. 305, pp. 503–505.

UN (United Nations). 2010. *Report of the Secretary-General's High-level Advisory Group on Climate Change Financing.* New York, UN. Available from http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/AGF_Final_Report.pdf

UNEP (United Nations Environment Programme). 2011. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication.* Nairobi, UNEP. Available from http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx

UNIFEM (United Nations Development Fund for Women). n.d. *Facts & Figures on Gender & Climate Change.* Available from http://www.unifem.org/partnerships/climate_change/facts_figures.php (Accessed 11 July 2011.)

UN-Water. 2009. *Climate Change Adaptation is Mainly About Water.* Key message prepared for the 15th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change. New York, UN-Water. Available from http://www.unwater.org/downloads/UNWclimatechange_EN.pdf

UN-Water. 2010. *Climate Change Adaptation: The Pivotal Role of Water.* Policy Brief. New York, UN-Water. Available from http://www.unwater.org/downloads/unw_ccpol_web.pdf

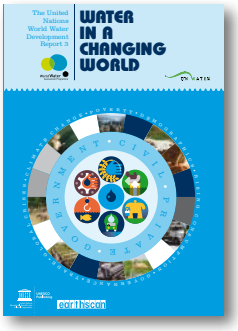
Winpenny, J. 2009. Capacity needs for water access and sanitation: Achieving the MDGs. *Capacity*, No. 36, pp. 4–7. Available from http://www.capacity.org

World Bank. 2010. *Economics of Adaptation Under Climate Change. Synthesis Report.* Washington, DC, The International Bank for Reconstruction and Development/The World Bank.

WWAP (World Water Assessment Programme). 2009*a*. *World Water Development Report 3: Water in a Changing World.* Paris/London, UNESCO/Earthscan.

WWAP (World Water Assessment Programme), 2009*b*. *Water and Climate Change.* Perugia, Italy, UNESCO-WWAP.

WWAP (World Water Assessment Programme). 2009*c*. *The Implications of Climate Change on Water.* Briefing Note. Perugia, Italy, UNESCO-WWAP.



The United Nations World Water Development Report 3: Water in a Changing World

Coordinated by the World Water Assessment Programme, the 2009 *United Nations World Water Development Report 3: Water in a Changing World* is a joint effort of the 26 United Nations agencies and entities that make up UN-Water. The report brings together some of the world's leading experts to analyse the state of the world's freshwater resources: it monitors changes in our water supplies and in how we manage them, and tracks our progress towards achieving international development targets.

The *World Water Development Report* also provides decision makers with the tools to implement sustainable use of our water – offering best practices to help stimulate ideas and actions for better stewardship of this most essential resource.

An accompanying case studies volume, Facing the Challenges, examines the state of water resources and national mechanisms for coping with change in 23 countries and numerous small island developing states.

United Nations Educational, Scientific and Cultural Organization
World Water Assessment Programme
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