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Background Note

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Adapting to climate change in the water sector

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Water is the key medium that links atmospheric temperature rises to changes in human and physical systems.

Climate change will alter the hydrological cycle in many ways. The trigger is the warming of the atmosphere and oceans, which will change major weather systems. This will alter the temporal and spatial patterns of rainfall with consequences for runoff, surface and groundwater storage, river flow regimes and, it is estimated, greater likelihood of extremes – droughts and floods – in different parts of the world.

These changes will, in turn, affect major human livelihood systems, particularly those dependent on direct access to natural assets. Rain-fed agriculture, human settlement patterns and movement, water supplies, sanitation and irrigation will all be affected, leading to changes in human health, wealth and security. On the demand side, as populations grow and move – and as their income levels increase or decrease – their demand for water resources will change, both spatially and temporally.

Taken together, the net effect of these supply and demand-side changes will present major challenges to future management of water resources for human and ecosystem development. Demand management, which aims to regulate withdrawals at sustainable levels through such measures as the promotion of sustainable use, pricing mechanisms, and water saving crop production techniques, will become increasingly important in areas where relative scarcity and competition between sectors is increasing. Supply side management will become a priority where inter-annual resource availability is likely to change significantly and where populations are more vulnerable. Supply side management, in general, involves increasing or augmenting the supply of water resources through increased storage capacity, abstraction from water course, rainwater harvesting and recharge activities and/or introducing incentives for water conservation.

The Intergovernmental Panel on Climate Change (IPCC) Technical Paper on Climate Change and Water states that 'water resource issues have not been adequately addressed in climate change analysis and climate policy formulations. Likewise, in most cases climate change problems have not been dealt with in water resource analysis, management and policy formulation' (Bates et al., 2008). This suggests a gap in the analysis required to understand the full effects of climate change on human and natural systems and, moreover, how policy makers can and should improve future responses to climate change at country, regional and international levels.

This background note outlines the state of existing knowledge and suggests better ways to build successful adaptation approaches into the water sector.

What do we know about the impacts of climate change on the water sector?

The impacts of climate change on the water sector can be divided broadly into knowns and unknowns. While there is greater certainty on the impact on the hydrological system (temperature, precipitation, evapotranspiration and snow and ice melt driving greater or lesser 'bulk' availability), how this leads to changes in runoff and river flows, flooding and drought patterns is less certain. This is because of the many human and physical feedback loops that determine resource behaviour at the more local scale. This uncertainty in social and physical systems behaviour is one of the most pressing areas of enquiry in understanding how

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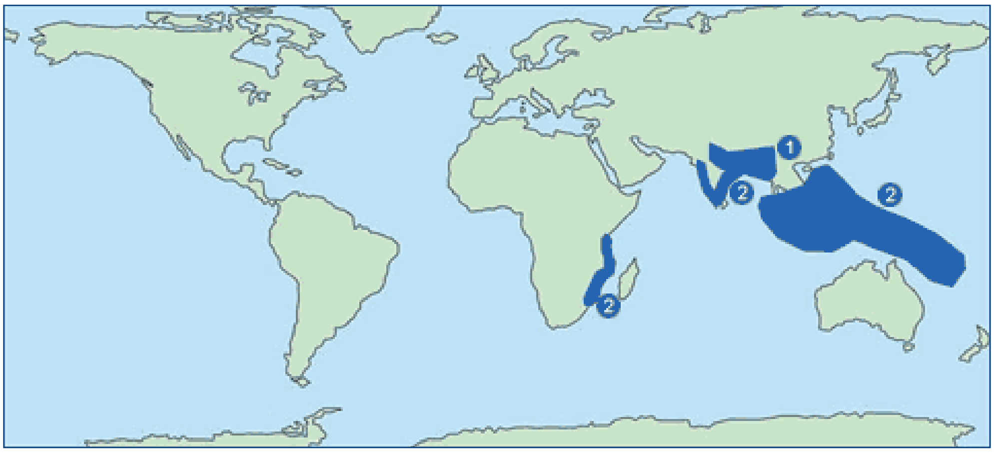
Map 1: Flooding risk

1. Large number of people at risk from seasonal flooding in Ganges, Brahmaputra and Meghna rivers
2. Large number of people at risk from sea-level rise



Source: UK Met Office, http://www.metoffice.gov.uk/climatechange/guide/effects/security.html

and where to intervene to mitigate the more harmful effects of climate change on the hydrological cycle. Without sufficient knowledge at this scale, policy makers and practitioners can make serious mistakes and generate 'maladaptation' responses.

What we know: changes in supply

Changes in precipitation: current projections based on the Special Report on Emission Scenarios (SRES) storylines depict a rise in global average surface temperature of approximately 1 degree centigrade by the 2020s. The temperature rise is associated with an anticipated increase in precipitation at higher latitudes (eastern Africa, the northern part of central Asia and the equatorial Pacific Ocean) and in the tropics, but decreasing precipitation in the sub-tropics (Mediterranean and Caribbean regions). There is greater certainty regarding changes in extreme precipitation compared to changes in mean precipitation patterns.

Changes in snow and ice-melt: globally, there is growing evidence that snow cover has already decreased in most regions, especially during Spring and Summer. Climate models used in the Arctic Climate Impact Assessment project a 9-17% reduction in the annual mean Northern Hemisphere snow coverage by the end of the century under the B2 scenario, which describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. Schneeberger et al. (2003) (in Bates, et al., 2008) based on simulations of 11 glaciers in various regions, project a volume loss of 60% of these glaciers by 2050.

Changes in evapotranspiration and soil moisture: there is little data on these, making it difficult to carry out a trend analysis. It might be assumed that any changes in this area will largely be related to changes in vegetation cover caused by land use change and other human development factors.

Changes in flooding and drought patterns: various country studies co-relate changes in snow and ice cover and precipitation patterns with an increased incidence of flooding and changes in river-flow. For instance, Agrawala, et al. (2003) highlight an increase in the likelihood of Glacial Lake Outburst Flooding (GLOF) in Nepal due to glacier melt. In sub-Saharan Africa, Conway et al. (2008) suggest that there is anecdotal evidence of increasing flooding in historically drought-prone areas like Ethiopia, with greater variability in precipitation patterns, particularly in intensity and duration. Projections indicate that summer low flows in the Rhine will decrease by 5-12% by the 2050s, which will have an adverse impact on water supply (IPCC, 2008). Similarly the Met Office at the Hadley Centre, UK, highlights that climate change will put a large number of people at risk as a result of seasonal flooding of the Ganges, Brahmaputra and Meghna rivers in the Asian sub-continent and the rise of sea-levels in Bangladesh (See Map 1 and Newborne, 2009, for further details). Projections also highlight that there will be severe increases in the Palmer Drought Severity Index (PDSI) between 2000-2046.

What we know: changes in demand – by sectors and regions

A number of drivers are already changing patterns of demand. These include population growth, land use change, economic growth and technological change

The most significant change is likely to be in the agricultural sector where climate-related factors will increase the future demand for water as a result of changes in precipitation, runoff and evapotranspiration rates. For instance, irrigation demand is projected to increase by 0.4%-0.6% per year up to 2030 and 2080, according to projections from the Food and Agriculture Organization (FAO). But if the anticipated impacts of climate change are added, the projected demand will lead to an increase of between 5-20% by 2080. On the other hand, the projected increase in household water demand and industrial water demand due to climate change is likely to be small – less than 5% by the 2050s in some locations (Bates et al., 2008).

Water demand is also likely to increase as a result of changes in human settlements, caused either by the primary or secondary effects of natural change, or because of government-driven policy that shapes the pattern and density of future settlements. It is projected that the sea level rise and resource scarcity linked to climate change will drive increased rural-urban migration patterns, and will increase the cost of water supply and sanitation infrastructure as a result of more frequent flooding, salinisation of groundwater, and the increased need to re-use available water.

A decline in water availability is also likely to have an adverse affect on the energy sector. According to Bates et al. (2008) 'A study of hydro-electric power generation conducted in the Zambezi Basin, taken in conjunction with projections of future runoff, indicates that hydropower generation would be negatively affected by climate change'. Climate policies, including those on biofuels production, which could increase water pollution through increased nitrogen-runoff and result in the overuse of water for irrigation, are also likely to have significant impacts on water demand at national and sub-national levels. In 2005, for example, ethanol production of 36,800 million litres (worldwide) led to a 2% increase in water withdrawals for irrigation. Projections indicate that this demand (depending on the type of crop grown and country conditions) will increase to 4% by 2030 as a result of the production of 141.2 billion litres of biofuel worldwide (Faures, 2008).

What we don't know: changes in water resource availability

Many aspects of the impact of climate change on water resource availability remain uncertain, stemming from: system complexity (climate, hydrological and socio-economic); the coarsely-grained nature of many models and impact assessment methods; and the difficulty in weighing up relative cause and effect, not least because of the possible reinforcing or mitigating effects of climate and non-climatic factors at a local level. This makes future projections of water stress at national and sub-national level – whether this stress relates to physical or economic scarcity – problematic.

There are, however, two broad trends in relation to climate change-induced water stress, which do not take into account adaptation:

1. There will be an increase or decrease in water stress. This includes an increase or decrease in physical scarcity and/or the replacement of current areas of economic and social scarcity by physical scarcity. These changes will be driven directly by climate-induced impacts on the hydrological system.
2. There will be an increase in economic and social scarcity. These changes will be driven by the impact of climate change on demand for water.

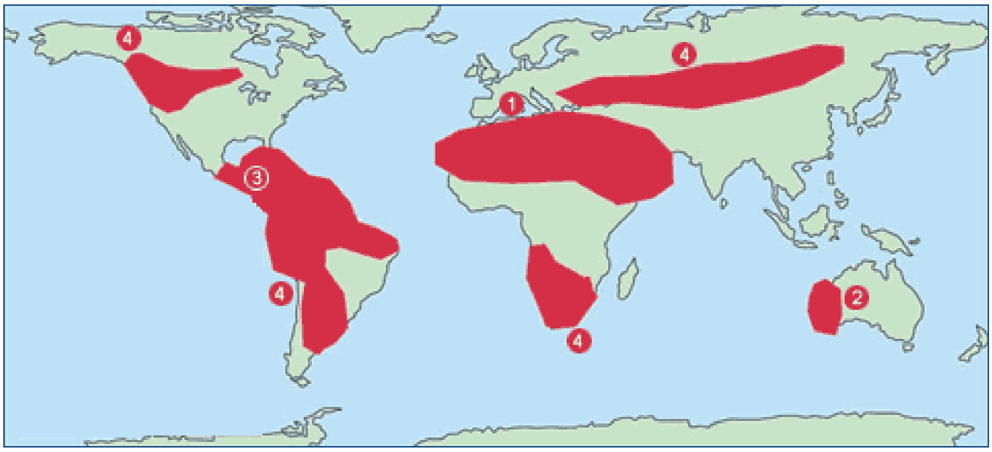
Arnell (2004), for example, argues that climate change will result in decreased runoff in some parts of the world, leading to increased water resource stress (see Map 2, overleaf). Similarly, the findings of Menzel et al. (2007), project that the number of people living in regions with severe water stress will increase from 2.3 billion in 1995, to 3.8-4.1 billion in the 2020s and to 5.2-6.8 billion in the 2050s. The main cause of increasing water stress will be growing water withdrawals as a consequence of growing population and improving economic conditions, rather than decreasing water availability.

In other water-stressed parts of the world (including southern and eastern Asia), climate change will increase runoff. This would result in greater per capita availability of water, but access will be determined by success in capturing and storing the resource for domestic and agricultural use (Arnell, 2004). Without sufficient adaptation mechanisms in place to regulate supplies, increased runoff in the wet season may exacerbate flooding, whereas decreased runoff in dry seasons may precipitate a future increase in drought frequency and intensity.

Economic water scarcity may increase as groundwater levels decline as a result of over-abstraction by some users, which would make water more expensive. In some parts of a country such as India this can mean that access to the resource is determined by wealth. While commercial farmers respond to groundwater depletion (to which they themselves contribute) by drilling down and pumping from deeper wells, smaller-scale users with shallower access points become

Map 2: Water stress and drought risk

1. Large decreases in river flow up to 70% by 2071-2100 across west Asia, the Middle East and the Mediterranean basin
2. Large decreases in river flow 40-60% by 2071-2100
3. Large decreases in river flow up to 70% by 2071-2100
4. Severe increases in Palmer Drought Severity Index (PDSI) 2000-2046



Source: UK Met Office, http://www.metoffice.gov.uk/climatechange/guide/effects/security.html

acutely vulnerable as wells dry up. Some are then forced to purchase water in 'markets' supplied by the same commercial farmers. Where sea-level rise is substantial and associated with coastal aquifers that suffer heavy abstraction, future saline intrusion may increase the damage to the potability of freshwater aquifers, particularly when combined with high population density and rapidly increasing demand.

A variety of social and political factors surrounding access to wealth and power resources – commonly due to access to land as much as water – compound the problems of access by poor households to domestic and non-domestic supplies. How governments respond to climate change and their understanding of impact on water supplies may well be determined by political and social forces as much as by the science itself.

Finally, climate change projections suggest that climate change will superimpose itself on current drivers of scarcity and is likely to replace areas of economic scarcity (most of Africa) with physical scarcity. While such projections are broad-brush, they have major implications for water resource management and policy making. At present, their continental-scale of application limits their use in policy discussions at national level, yet this is the level where development is largely engineered through policy choices, budgeting priorities and other governmental and non-governmental instruments of social change and economic choice. This is where the decisions are made on most mitigation and adaptation measures and where those decisions will be implemented and reviewed for their effectiveness.

Adapting to the impacts of climate change in the water sector

Adaptation strategies in the water sector will need to address a number of emerging trends driven by climate change. These include increased uncertainty, variability and extreme weather events. Social and political contexts will further determine the net impacts of climate change on social systems and on the effectiveness of adaptation interventions.

This section outlines the broader approaches that are being proposed to facilitate adaptation to climate change as well as those that are specific to the water sector.

On general approaches, the Adaptation Policy Framework (Lim and Siegfried, 2004) outlines four broad options:

1. Hazards-based approach, which aims to reduce climate induced risks. This approach assesses the current risk to which a system is exposed and then uses climate scenarios to estimate future vulnerability.
2. Vulnerability-based approach, which aims to ensure that critical thresholds of vulnerability in socio-ecological systems are not exceeded under

climate change. Vulnerability assessment takes into account both development conditions and sensitivity to climate change.

3. Adaptive-capacity approach, which starts with an assessment of current adaptive capacity and aims to increase this capacity to enable systems to better cope with climate change and variability;
4. Policy-based approach, which aims to ensure that policy is robust under climate change.

In terms of planned interventions, a number of technical, policy and market based instruments are being formulated. Under the broader approaches, these include: 'mainstreaming', which requires development planning to take into account the effects of climate change; insurance frameworks, which build adaptive capacity; disaster risk preparedness and reduction, which aims to reduce climatic hazards; and safety net programmes, which aim to reduce the vulnerability of local communities (Table 1).

Table 1: Broad adaptation approaches and tools

Approaches	Tools
Hazards-based approach	Building physical infrastructure, such as sea walls, dykes and river bunds; Disaster Risk Reduction and Preparedness planning
Vulnerability-based approach	Safety Net Programmes; strengthening livelihood asset availability
Adaptive-capacity approach	Insurance; improving technological know-how
Policy-based approach	Mainstreaming within sectors; Climate proofing

Specific to the water sector, the IPCC Technical Paper on Water (2008) outlines three approaches that can be used to address climate change adaptation planning in the light of uncertainty in future hydrological conditions. These include:

1. Scenario-based approaches to planning – to develop plausible future storylines to facilitate decision making in the context of uncertainty. Scenario development is based on a set of assumptions of the key relationships and driving forces of change. These include predictable and unpredictable features of changes in climate, the environment and socio-economic factors. Existing scenarios include those developed by the IPCC and the Millennium Ecosystem Assessment. Scenario-based planning is being practiced in the UK and Australia.
2. Adaptive management – which involves the increased use of water management measures that are robust enough to withstand uncertainty;
3. Integrated Water Resource Management (IWRM) – includes: taking on board diverse stakeholders; reshaping planning processes; coordinating land and water resources management; recognising water quantity and quality linkages; conjunctive use of surface water and groundwater; and protecting and restoring natural systems. IWRM can ensure inclusive decision-making and resolve conflicts between competing water uses and, therefore, facilitate adaptation in the water sector. However, in order to address the impacts of climate change, IWRM will need to consider the different types of uncertainties in the management process and the system itself (Pahl-Wostl et al., n.d.).

In the water sector, planned interventions include both supply and demand side. While supply side adaptation options involve increases in storage capacity or abstraction from water courses; demand-side options, like increasing the allocative efficiency of water to ensure that economic and social benefit is maximised through use in higher-value sectors, aim to increase value per volume used and to ensure that quality is maintained.

Current examples of planned interventions in the water sector can be found in the National Adaptation Programmes of Actions (NAPAs) that have been prepared by Least Developing Countries (LDCs) (UNFCCC 2008). These allow the LDCs to identify priority activities that respond to their priority needs on adaptation to climate change. They aim to enhance existing adaptive capacity at a local level, rather than focusing on scenario-based modelling to assess future vulnerability and long term-policy at a state level

Of the 64 identified water sector interventions, 34 are technical interventions, six can be categorised as institutional/policy based interventions; and only one is a market-based intervention (for example, Kiribati aims to put in place demand-based pricing mechanisms that will enable the purchase of monitoring equipment and payment for water based consumption). The others use a mix of tools.

Most of the identified interventions are supply-side interventions. Only a few examples, including Eritrea and Lesotho, aim to put in place demand and supply side legislation to manage irrigation wells and ensure sustainable water use.

As outlined in the NAPA preparation manuals, most of the interventions address current and local specific vulnerability. Almost all of them aim to address inter-annual variability (such as Bhutan, Burundi) or extreme weather events (Kiribati). There are only a few interventions that aim to address long-term climate change (including Bangladesh and Maldives).

Table 2: Adaptation interventions in the water sector

Type of intervention	Intervention	Addresses demand (D) or supply (S)	
		D	S
Institutional/Policy	Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise (Bangladesh)		*
	Mobilisation and integrated water resource management project (Cape Verde, Vanuatu)	*	*
	Implementation and management of water management associations (Madagascar)	*	
	Contribution to better knowledge of surface water regimes (Mauritania)		
	Institutional strengthening of water resources sector (Sierra Leone)		*
Technical	Rainwater Harvesting (Bhutan, Burundi, Mali, Sierra Leone)		*
	Groundwater recharge for irrigation wells (Eritrea, Mauritania)		*
	Use of spate, drip irrigation and range land development (Eritrea, Mauritania)	*	*
	Stabilisation of river dynamics and water courses (Burundi, Mauritania, Mozambique)		*
	Coastal Protection infrastructure (Maldives)		
	Increased water supply (2 Cambodia, 2 Comoros, Djibouti, Burkina Faso, Gambia, Guinea Bissau, Kiribati, Maldives, Mauritania, Niger, Samoa, São Tomé and Príncipe, Sierra Leone, Tanzania, Tuvalu)		*
	Development and Improvement of small-scale and Community Irrigation systems (Cambodia, Ethiopia, Guinea Bissau, Rwanda		*
Market	Water resource adaptation project (Kiribati)	*	

Very few interventions attempt to address issues of social and political access. Water supply and irrigation projects in Cambodia and Eritrea aim to establish water user communities. Others, like those in Guinea Bissau, São Tomé and Príncipe and Lesotho co-relate improved access to investments in physical infrastructure.

In terms of contributing to adaptive management, a few have a monitoring and evaluation (M&E) component. M&E in these projects attempts to assess the socio-economic impact of the intervention (Bhutan); the status of water resources (Kiribati); and the number of losses avoided or reduced through early warning messages (Mauritania). However, a co-relation between such M&E components still needs to be struck, with top down frameworks and proposals, including the Global Environmental Facility's results-based management framework, which focuses on the performance and achievement of adaptation projects and the concept of 'measurable, reportable and verifiable' as proposed by the Bali Action Plan, which is likely to include indicators based on result and process oriented adaptive capacity (UNFCCC, 2008a).

Table 2 (above) depicts interventions identified in NAPA documents. These are likely to play a role in reducing climate-induced hazards and vulnerability as well as build adaptive capacity.

In terms of autonomous adaptation to deal with climate-induced impacts on water resources, studies have documented a number of interventions (see UNFCCC Database on local coping strategies). These include changing crop types, planting timings, tilling methods, sale of assets and so on. It has also been found that farmers who are well off are likely to respond to market conditions rather than climate threats (Ziervogel et al., 2006; Snidvongs, 2006). While responding to the market may encourage risk taking and growth, it can also lead to maladaptive practices and increased vulnerability in cases where planned adaptation options like insurance do not exist and short-term profit maximisation (through, resource 'mining') is prioritised over longer-term conservation.

Autonomous adaptation at household level may not be able to challenge the political dimensions of the impact of climate change, which includes the appropriation of access to water by powerful élites and control over the flow of knowledge as well as the resource itself.

Care must be taken while developing planned adaptation policies to ensure that they provide suitable options for different farm scales (Eakin, 2000; Burton and Lim, 2005). They should be responsive to socio-economic and political contexts to ensure that different scales can take advantage of the adaptation policy.

How will our current knowledge on climate change help us plan future interventions in the water sector?

Although there is a high level of uncertainty about impacts at the national level and below, there are a number of trends emerging from the current state of knowledge of climate-induced impacts and policy responses that point to some ways forward.

As highlighted by Milly, et al. (2008), climate change challenges the underlying principles of water management, which include decision-making based on historical trends and notions of predictable variability in precipitation and river flows. Given the new challenges posed by climate change, adaptation in the water sector will be about responding to longer-term challenges that go beyond annual or even triennial planning cycles. This involves building capacity to develop more sensitive analysis of what is changing in hydrological systems, how these changes may or may not be climate-specific and the relative balance between climate-induced change and other factors including demography. Lake-level decline may be a combination of changes in inflows, increased abstraction and greater evaporation, for example.

More sensitive analysis needs to be combined with stronger scenario planning that takes as its starting point the development needs of populations. What will demand be, and why, in time and space across different sectors, and what are the likely 'bads' to avoid and 'goods' to support? Proper scenario planning can help in choosing the best management options that address this question at national scale, but also between countries sharing a basin, such as the Nile. At this scale the idea of allocative efficiency is important so that large-scale 'mal-adaptation' is not literally set into the concrete of dams, irrigation schemes, flood defences and other infrastructure, built in the wrong places in the wrong countries.

The kind of integrated management approach encapsulated in the concept of Integrated Water Resources Management (IWRM) is an approach that can, with sufficient financing and institutionalisation, help in making the right kinds of decision in the right way. Yet current knowledge of this approach shows that it is difficult to institutionalise, not least because previous attempts have been dominated by water-sector institutions, and governments are rarely committed to financing IWRM implementation because of the considerable inter-sectoral coordination, and the logistical difficulties that must be overcome to make it succeed.

While development needs and projections should be a starting point, there will be limits to the demand and supply-side social, physical and economic instruments and their capability in ensuring sufficient water is available and at the right price to meet those needs. Future planning also needs to take heed of the changing colours on 'water stress' maps, and to develop more comprehensive resource and drought mapping of their own. This level of better information and use of information is perhaps the starting point for improved sector responses to climate change.

Existing policy frameworks can help – and the IWRM framework is a good starting point – but to become a major force in adapting to climate change they need to be sustained financially and institutionally by government at national level and below. At present, the climate change debate is focused mostly on the extremes, risk and media-friendly scenarios of change. The more mundane development of better planning that is more informed and inclusive should receive far more attention.

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