A United Nations World Water Assessment Programme Special Report

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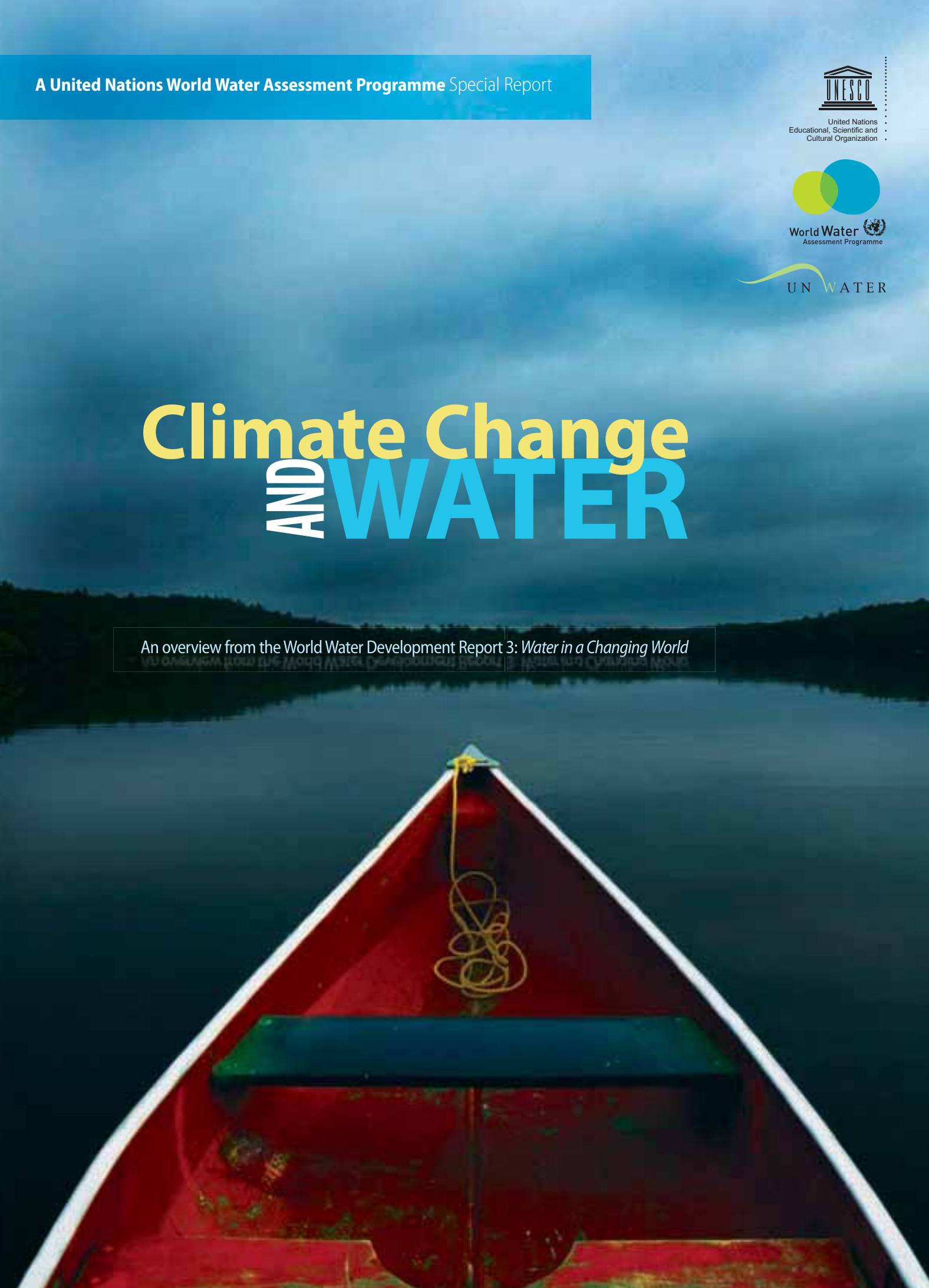
UN WATER

Climate Change AND WATER

An overview from the World Water Development Report 3: *Water in a Changing World*



CLIMATE CHANGE AND WATER

AN OVERVIEW FROM THE WORLD WATER DEVELOPMENT REPORT 3: WATER IN A CHANGING WORLD

A WORLD WATER ASSESSMENT PROGRAMME SPECIAL REPORT

The World Water Assessment Programme is most grateful to Joana Talafre and Friederike Knabe for their valued contributions to the preparation of this report

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Foreword

Water is an integral component of climate change and the primary medium through which it exhibits its impacts. With the world facing growing water challenges in many regions, how climate change will affect future societies cannot be understood without looking at its impact on this most vital of our planet's resources.

This World Water Assessment Programme Special Report brings together messages on water and climate change from the *World Water Development Report 3: Water in a Changing World*. A joint effort of the 26 United Nations agencies that make up UN-Water, the triennial World Water Development Report is the United Nations' foremost and most comprehensive review of the state of the world's freshwater resources.

Water in a Changing World shows that changes in our water resources are shaped to a great extent by a number of key externalities, among them climate change, and that decisions taken far from the conventionally defined water sector have a tremendous influence on water resources and how they are used or misused. These two principle messages of the report could not be timelier, with the challenges of climate change currently being squarely addressed and innovative responses sought with such enthusiasm. *Water in a Changing World* describes the dynamic linkages that interconnect changes in climate, the state of our water resources, demographic expansion and migration issues, food and energy shortages, and the continuing challenge of poverty. Rather than addressing these issues in isolation, it argues that a holistic approach is crucial if we are to solve the crises we face today and avoid worse crises tomorrow.

Climate change directly affects the water cycle and, through it, the quantity and quality of water resources available to meet human and environmental demands. It can lead to both floods and drought. Rising sea levels have a serious effect on coastal aquifers, a major source of urban and regional water supply systems, and higher water temperatures and changes in extremes can exacerbate many forms of water pollution. Water supply reliability, health, agriculture, energy and aquatic ecosystems – all will feel the impact of these changes to the water cycle. The demand for water to meet these needs is also affected by climate change. The importance of water to sustainable social and economic development cannot be underestimated, yet many countries are already facing multiple water challenges, all of them compounded by climate change.

While mitigation of anthropogenic climate change is vital, the blunt reality is that all countries must also adapt to climate change – particularly developing countries, which are often especially vulnerable to climate change and many of which will be hit hardest and earliest. Even if greenhouse gas concentrations stabilize in the coming years, some impacts from climate change are unavoidable. These include increasing water stress in many regions, more extreme weather events and the potential for large population migration.

Adaptation to climate change will demand a firm commitment from leaders in government, private sector and civil society worldwide. Public policy on key water services and functions must prioritize a strengthening of competencies and institutions, and ensuring the infrastructure investment necessary for long-term water security. But policy choices and other decisions made outside the water domain are also crucial if we are to change and improve how water is allocated and used, as well as making the adaptation to new, more efficient management systems more effective and less costly. The international community will have to balance investments to reduce risks and to prepare for increasingly severe climate events against investments to improve responses to the crises already being experienced today. Both are vital, and focusing on today's problems can also create greater resilience for dealing with the problems of tomorrow.

Carbon is a measure of the anthropogenic causes of climate change; water is a measure of its impacts. We must act now, and act together, if we are to rise to the challenges of climate change to ensure long-term economic, environmental and social sustainability and avert a global water crisis.

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Synopsis

Climate change has undeniable impacts on water. It has and will continue to impact the water cycle in direct and indirect ways: by affecting precipitations and evaporation cycles, as well as by changing patterns of consumption. In turn, evolving consumption patterns and economic development will increase demands on water supply.

Climate change is experienced most directly through its impacts on water availability. Some countries are already experiencing serious water shortages or are reaching the limits of their water resources. The effects of climate change are likely to aggravate this situation even further.

Water-related vulnerabilities occur through multiple, mutually-reinforcing linkages: food, health and energy, in addition to physical and economic vulnerabilities. For many countries, especially developing countries, water availability and management are already at the root of a complex vulnerability dynamic and challenges are likely to increase with climate change, thereby having an undeniable effect on development progress and achievement of Millennium Development Goals (MDGs). Least developed countries are the most vulnerable, as their present water resource management technologies and capacities are inadequate and insufficient.

It is vital that responses to climate change must focus on water. Addressing water resource management is recognized as a priority, and is an inescapable part of reducing vulnerability and promoting adaptation to climate change. A balance between mitigation and adaptation strategies has to be established at policy and programme levels so that 'win-win' solutions can be realized.

Competition for water is intensifying: between countries, urban and rural areas, or different sectors of activity. This could make water an increasingly politicized issue. Holistic and multisectoral approaches have to be taken when developing adaptation strategies.

Agriculture, as the sector requiring the largest percentage of water resources, is a primary area for development of adaptation strategies. There exist a variety of 'no-regrets' solutions that will help address current and possible future water-related vulnerability and generate multiple development benefits, regardless of climate scenarios.

Proactive adaptation requires enabling policy conditions at all levels:

- At national levels, water governance must be expanded to, and integrated with, non-water sectors; access to technology, science and information should be increased for sound planning; and development efforts need to be checked for what could be maladaptations with regards to water.
- At regional levels, collaborative water management for shared surface and groundwater should be emphasized. There exist numerous models for sharing water that provide equity, as well as rational management.
- At the international and global level, financing for water-related investments should be increased, including for infrastructure, technology.

1 Climate change has undeniable impacts on water

- There is evidence that the global climate is changing.
- Water is the primary medium through which climate change impacts the earth's ecosystem and people.
- Climate change is the fundamental driver of change in the world's water resources and adds additional stress through its effects on other externalities.
- Human activities affect demand on the world's water supply, which in turn, impact on climate change.

Human societies have always lived with uncertainty and variability in climate. We have learned to adapt to the realities of our given environment, yet our requirements for water to meet our fundamental needs and our collective pursuit of higher living standards, coupled with the need for water to sustain our planet's ecosystems, make water unique among our planet's natural resources. Water is essential to life, sustainable economic growth and the functioning of ecosystems: but the water supply is finite.

Climate change could alter the timing, magnitude and duration of rainfall and other weather events. All evidence shows that climate variabilities have increased to such a degree that predictability of water availability has been reduced dramatically: weather extremes are shifting and intensifying, and thereby introducing greater uncertainty in the quantity and quality of our water supplies over the short and the long term. Climate change is usually described as the supply-side 'driver' that will ultimately determine how much water we have available.

We can and must, therefore, manage the interaction between human demands (demand-side drivers) on our water supply and naturally occurring changes in climate patterns, which are increasingly intensified through climate change. These demand-side drivers include economic, social and demographic pressures – all affected by a range of factors from technological innovation to institutional and financial conditions. How we manage these 'demand drivers' will affect climate change.

1a Direct ways in which climate change impacts the water cycle: effects on precipitation and evaporation cycles

Climate change directly affects the water cycle, and through it, the quantity and quality of water resources. It can lower minimum flows in rivers, affecting water availability and quality for drinking water, flora and fauna, energy production (hydropower), thermal plant cooling and navigation. Climate change also creates variations in water storage and fluxes at the land surface; in storage in soil moisture and groundwater, glaciers and seasonal snow packs; in the surface water of lakes, wetlands and reservoirs; and in precipitation, runoff and evaporative fluxes to and from the land surface.

Direct impacts of climate change on the water cycle could mean that some regions will become dryer and turn into arid and semi-arid regions, or even deserts. Changes in water cycles will threaten the survival of fragile ecosystems in these regions, and consequently endanger the lives of people who depend on the natural resources that these ecosystems provide. Already today, more than 40% of the world's land resources are in drylands (i.e. sub-humid, semi-arid and arid regions) that are threatened by land degradation and desertification. This has a direct impact on a quarter of a billion people, and an indirect impact on more than a billion people (UNCCD 2008). The coping mechanisms used by those living with regular cycles of water scarcity are likely to become obsolete or no longer adaptive to new and changing environmental conditions. Local biodiversity, essential for ecosystem survival, as a result will be further threatened.

Other regions will experience dramatic increases in disasters, such as floods caused by typhoons and hurricanes. Rainfall that exceeds the carrying capacity of the water channels can also cause flooding, threaten the infrastructure of water systems and endanger ecosystems. Changing water cycles caused by climate change will affect food production, land use and survival of plant and animal species.

The development of water management strategies must, therefore, take climate change into account, as it adds to uncertainty and unpredictability in the water supply.

1b Indirect effects of climate change on the water cycle: migration and changing patterns of consumption

Drought, desertification and other forms of water scarcity are already estimated to affect as many as one-third of the world's people and are predicted to worsen, affecting consumption and migration patterns in many parts of the world.

Migration

The direct supply-side effects of climate change outlined previously, including increased water scarcity, flooding, accelerated glacial melting and rising sea levels, have the potential to accelerate human migration.

Rural-urban migration and migration in response to political conflict and environmental crises are other growing demographic drivers affecting water resources and allocations. The UN World Water Development Report 3: Water in a Changing World (WWDR-3) estimates the potential of environmentally displaced people (likely displaced as a result of water-related factors) to be in the range of 24 million to almost 700 million. Such migration would seriously impact development projects designed to relieve future stresses on water availability. Part of the complexity in unravelling the connection between migration and environmental factors, such as water resources, is that people rely directly or indirectly on the natural environment for their livelihoods. In addition, development policies and political and economic stability – or the lack thereof – can affect both migration and water resources. Given these complexities, it is difficult to estimate the magnitude of potential migration as a result of environmental factors (WWDR-3, page 32).[1]

Changing consumption patterns

While climate change is clearly the supply-side driver affecting the availability of water resources, human demands also interact with climate change to exacerbate the pressures on the water supply. Currently the most important demand-side pressures on water arise from population growth in the early stages of a country's development and, with further development, consumption choices in the wake of rising per capita incomes. As incomes grow, people consume more – and thus more water will be needed; for instance, to produce food for tens of millions of people moving from one meal to two meals a day and/or to produce the increasing amount of meat that may be included in their diets.

As countries develop, rising standards of living also boost the demand for non-food items and services, many of which have a large ecological and water footprint. Whereas in developed countries consumers and corporations are increasingly being encouraged to reduce their water footprints, large amounts of water are used to produce and process non-food goods and services (virtual water content), adding to pressures on the quantity and quality of water resources. The concept of 'virtual water' has been introduced to reflect the indirect use of water that leaves a country in exports and enters another through imports as integral part of goods that use water for production.

Other external forces that may create either positive or negative pressures on water resources include pricing policies and subsidies for water and water-related goods, trade patterns, developments in science and technology, consumption patterns, evolution of policies and laws, social movements, and politics at global and national levels. These external forces, unlike climate change, will not create pressures directly (or only) on water management. But climate change will exacerbate the uncertainty surrounding all these development drivers, because it reduces the predictability of water resources available to fulfil the other societal and economic demands.

Managing water resources is made more difficult by a lack of knowledge and information required for decision-making and long-term planning. Few countries know how much water is being used, for what purposes, nor the quantity and quality of water that is available. Few know how much water can be withdrawn without serious environmental consequences, nor the amount of finance being invested in water management and infrastructure. Climate change complicates these uncertainties.

1 WWDR-3: World Water Assessment Programme, 2009, *The United Nations World Water Development Report 3: Water in a Changing World.* Paris: UNESCO Publishing, and London: Earthscan.

2 Water is at the root of a complex vulnerability dynamic

- Water resource management impacts almost all aspects of the economy, in particular, health, food production and security, domestic water supply and sanitation, energy, industry and environmental sustainability.
- Climate variability, water resource management and economic development are intricately linked.
- Vulnerability to natural disasters affecting the water supply hampers economic performance and undermines poverty reduction goals and achievement of the MDGs.

History shows a strong link between economic development and water resources development. There are abundant examples of how water has contributed to economic development and how development has demanded increased harnessing of water. Such benefits have come at a cost and, in some places, have led to increasing pressure on the environment and increasing competition among users.

Weather-related disasters, such as floods and droughts, are undermining economic development in many of the world's least developed countries, causing human suffering and disrupting economic activities. WWDR-3 argues that the availability of water and the skill with which it is managed are determinants of a country's growth trajectory. Good water management is normally the precondition of sustainable development.

There is clear evidence of a relationship between climate variability and economic performance in countries in which agriculture represents a large share of the country's Gross Domestic Product (GDP). The ensuing challenges will be of particular importance and concern in sub-Saharan Africa and other Least Developed Countries (LDCs) where rainfed farming systems are reliant on more or less predictable weather patterns. Evidence also suggests a strong relationship between economic development and vulnerability to disaster. Across developing countries, losses associated with disasters are so large as to undermine development and poverty reduction goals. Yet climate risks are seldom adequately considered in infrastructure designs, agriculture investments and water management plans of these countries, or of the donor community. Substantial financial and other development resources are being diverted each year to post-disaster relief, emergency assistance, reconstruction and rehabilitation. Poorly managed climate risks also discourage private investment.

Competition for water and shortcomings in managing water supply systems to meet the needs of society and the environment call for enhanced societal responses through improved management, better legislation, and more effective and transparent allocation mechanisms. Water management choices should emerge from informed consultation and negotiation on the costs and benefits of all options after considering relationships between land and water resources, water basin interconnectedness, and the consistency and coherence of decisions with other government policies.

Water and the Millennium Development Goals

The Millennium Goals include the following water-related targets:

'To halve, by the year 2015, the proportion of the world's people whose income is less than one dollar a day and the proportion of people who suffer from hunger and, by the same date, to halve the proportion of people who are unable to reach or to afford safe drinking water.'

'To stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies.'

2a Water availability and poor water management are at the root of vulnerability for many countries already and this is likely to increase with future climate changes, having an undeniable effect on development progress and achievement of the Millennium Development Goals; adaptation strategies are needed urgently

Properly managing water resources is essential to socioeconomic development, poverty reduction and equity – all crucial for achieving the Millennium Development Goals (MDGs). The Millennium Declaration placed safe drinking water and basic sanitation firmly among development objectives, making these a target of Millennium Development Goal 7. But while adequate progress is being made globally towards the provision of safe drinking water, the sanitation target is far from being met. Despite progress, the scale of the challenge remains massive. Large regions of the world, in particular in sub-Saharan Africa and low-income Arab states, are far from reaching the global target, while some risk backsliding.

The contribution of improved drinking water and sanitation to the achievement of all the MDGs is now well established. The WWDR-3 demonstrates this link throughout; others have elaborated the direct and indirect contributions of water management across all the MDGs. Climate change will increase the vulnerability of water supplies and underscore the importance of the targets at local, national and global levels.

One of the most pressing challenges of climate change is addressing the vulnerability of human populations, particularly the poor, to the impacts of extreme hydrologic events such as floods, storm surges and droughts. This must be done in concert with the creation of sustainable and resilient development opportunities that take into account projected climate conditions. Over the longer term, the effects of incremental climate change are likely to influence decisions about food security, energy security and land use, all with vital implications for water resource management and environmental sustainability. In this context, climate change can intensify existing pressures, thereby increasing risk, vulnerability and uncertainty.

Some parts of the world have no shortage of water; others, such as North Africa; large regions of sub-Saharan Africa, the Middle East and Australia; and parts of South Asia, South-East Asia and South America, suffer scarcity because of low annual rainfall. Many regions suffer from seasonal scarcity or from extreme seasonal rainfall, causing floods. Some suffer from both low and extreme rainfalls, at different times, leading to high variations in river runoff levels, land degradation, and loss of top soil and crops in the process, thereby weakening already fragile ecosystems while increasing food insecurity and poverty. Given the vital economic importance of rainfed farming for many developing countries, upgrading farming systems will form a major part of the response to the growth in demand for food and the reduction of hunger as part of the MDGs. According to one estimate, 85% of the freshwater required to meet the hunger goal will originate from rainfed agriculture.[2]

In some large countries, such as Mozambique and the United States, parts of the country may experience damaging intensive rainfalls while other parts may suffer prolonged drought. These variations matter most where they affect large populations or where the infrastructure cannot adequately handle the distribution of water resources and other necessities, such as in some of the LDC countries.

Scarcity – low available water per capita – is forecast to worsen where population growth is still high, as in sub-Saharan Africa, South Asia and parts of South America and the Middle East. Climate change and variability will affect the poorest and most marginalized groups, making them even more vulnerable. Climate uncertainty – the inability to anticipate climate extremes – also discourages investment and innovation, and dampens the effectiveness of development efforts.

Adapting to climate change adds a critical challenge to this picture for all countries, particularly for developing countries and for cities in coastal areas. Climate models show that extremes of rainfall are likely to worsen, resulting in more floods and droughts in regions already affected – often regions with low-income levels per capita, widespread poverty, high population growth and rapid urbanization.

Adaptation capacity will vary from country to country, with developing countries having the most urgent need for adaptation strategies to be developed and/or strengthened, especially among their vulnerable populations. In poor communities where survival is the main concern, people may have few choices about how they use land and water; the perceived risks of alternatives could outweigh their potential benefits. This is why the most successful integrated rural development initiatives are taking a holistic approach and are designed to help such communities reduce risks, develop alternatives and bring trade-offs to the forefront in decision-making.

Adaptation capacity within countries will depend on a range of preconditions, including awareness and appreciation of climate information and of the investment potential for adaptation strategies. Comprehensive climate information that allows for increasingly reliable projections will be vital for the development of any adaptation strategy. Given that agricultural societies are especially vulnerable to climate change, they will have to introduce changes in their farming systems to ensure continued food security and nutrition levels.

Lack of detailed climate knowledge, however, should not preclude or delay action now. Governments and societies cannot cope well with existing climate variabilities. Building adaptive capacity and tackling current conditions will not only alleviate existing problems, but will also increase the adaptation potential for impending and future climate changes.

2 **'Sustainable pathways to attain the Millennium Development Goals: assessing the key role of water, energy and sanitation'. Stockholm Environment Institute, Aug 2005.**

2b Water-related vulnerability occurs through multiple, mutually-reinforcing linkages: health, food, energy, in addition to physical and economic vulnerabilities

The water situation and the vulnerability of poor communities present a strong case for urgent actions on climate change. Projections warn of changes in water availability and quality that could have disastrous consequences. As the principal medium through which climate change will affect economic, social and environmental conditions, water should be at the apex of adaptation efforts.

Changes in water availability will have economy-wide impacts. While policy makers appear motivated to respond to the impacts of future climate change, they are less inclined and unmotivated to act on the water crises that are evident today. Even without climate change, development is threatened in many regions by factors that given national governments and the international community have already failed to address time and again as regards current climate variabilities. The April 2008 report on water by the Intergovernmental Panel on Climate Change (IPCC) points this out clearly (*see* Box 1.10 on page 73 of the WWDR-3, reproduced below).

The IPCC report notes that millions of people in densely populated low-lying coastal areas risk increasing exposure to flooding by storm surges over the 21st century. Current IPCC projections of rising temperatures and sea levels and increased intensity of droughts and storms suggest that substantial population displacements will take place within the next 30–50 years, particularly in coastal zones. All of these climate-change refugees will require shelter, water and sanitation services.

Gender

Women in developing countries and fragile ecosystems face multiple challenges. Already disadvantaged through gender inequity and a higher level of poverty, women are more dependent on reliable water resources in their vicinity because of their role in food production and family responsibility, as explained in Box 2.3 on page 38 of the WWDR-3. An increased involvement by women in awareness raising and decision-making is of vital importance.

Health

Every year in developing countries an estimated 3 million people die prematurely from water-related diseases. The largest proportion of these deaths is among infants and young children, followed by women from poor rural families who lack access to safe water and improved sanitation. Global warming can expand the endemic zones of water-related infectious diseases, like dengue, malaria and schistosomiasis, making it increasingly difficult for people to remain in affected areas. Such trends are already noticeable today. Recurring floods or storm surges, if not managed effectively, could

Box 1.10 Intergovernmental Panel on Climate Change Technical Report on Water and Climate Change

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

Source: IPCC 2008.

UN World Water Development Report 3: Water in a Changing World, Box 1.10 (page 19)

Box 5.3 Health and climate change

Climate change can affect health through multiple pathways, such as greater frequency and intensity of heat waves, fewer cold-related illnesses, increased floods and droughts, changes in the distribution of vector-borne diseases and effects on the risk of disasters and malnutrition. The overall balance of impacts on health is likely to be negative, and populations in low-income countries are likely to be particularly vulnerable to the adverse effects. However, many of the projected impacts of climate change on health are avoidable. Climate change is expected to exacerbate some health problems rather than cause new diseases to emerge. Strengthening public health prevention strategies, including improving water supply and sanitation services and disease surveillance, would be an essential part of any effective response.

Source: Haines et al. 2006; Campbell-Lendrum, Corvelan and Neira 2007.

UN World Water Development Report 3: Water in a Changing World, Box 5.3 (page 73)

drive large numbers of people permanently from their homes, resulting in refugee movements and migration. The effect of climate change on health is discussed in Box 5.3 on page 73 of the WWDR-3.

Food

Agriculture is by far the largest consumer of freshwater. Globally, about 70% of freshwater withdrawals go to irrigated farming, and far greater volumes of water are used in rainfed agriculture. The recent steep rise in food prices has damaged many food-importing countries. The problem has been compounded by the rising demand for food caused by growing populations and shifting diets, production shortfalls, increased costs of crucial inputs such as fertilizers (driven by energy prices), incentives to produce bioenergy, all of which are exacerbated by market speculation in trade practices.

Current climate variabilities already present serious challenges for food security in many developing countries. Rurally based populations in countries that rely on rainfed agriculture and primarily depend on subsistence farming systems are especially vulnerable. In general, water scarcity can limit food production and supply, putting pressure on food prices and increasing countries' dependence on food imports. But although the number of countries and regions without enough water to produce their food is rising as populations increase, the situation can be remedied in many developing countries by investing in water infrastructure, markets, credit, agricultural technology and extension services. Investment in water infrastructure is required to meet basic needs in rural areas and to enhance agricultural productivity through better water management.

Energy

Demand for energy – for heat, light, power and transportation – is increasing rapidly. The combination of high prices and a desire to substitute other sources of fuel led to the recent increase in the production of bioenergy, which has potentially important impacts on water quality and availability. Hydropower may be a renewable and non-polluting source of energy in some countries. Water for cooling is needed for all thermal sources of power, including nuclear. In the United States, water withdrawn for cooling (39%) is equal to the share of water use in agriculture. At the same time, energy is required to lift groundwater, pump it through pipes and treat both groundwater and wastewater. An estimated 7% of all energy produced is used for such purposes. Increased demand for water through desalination may increase energy demand in some countries, although on a global scale this demand is marginal.

Box 2.3 The role of women within the water sector & the importance of gender mainstreaming

In most developing countries gender inequity persists in access to and control of a range of productive, human and social capital assets. Consequently, the core components of poverty (capability, opportunity, security and empowerment) differ along gender lines.

In the water sector women labour to provide water for household needs while men make decisions about water resources management and development at both the local and national levels. Women draw water for household use, transport it home and store it until it is used for cooking, cleaning and washing. In areas of low water coverage women collect water from drains, ditches or streams that are often infected with pathogens and bacteria, causing severe illness or even death. In addition, women spend considerable time collecting water at the expense of income-generating activities. This also exposes them to sexual abuse and other forms of violence and leaves less time for girls to attend school.

Lessons from Africa and the rest of the world have demonstrated that increased participation by women in decision-making leads to better operation and maintenance of water facilities, better health for the community, greater privacy and dignity for women, more girls attending school and increased income opportunities for women.

The immediate action by water sector participants is to ensure gender mainstreaming in any planned action, including legislation, policies and programmes in all areas and at all levels. This will ensure that the voices of marginalized and disadvantaged women and men are integrated in design, implementation, monitoring and evaluation of policies and programmes and therefore help to achieve sustainable water provision for all.

Source: Adapted from Mutagamba 2008.

UN World Water Development Report 3: Water in a Changing World, Box 2.3 (page 38)

2c Possible futures for climate and water

The IPCC contends that 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 even satisfactorily cope with current climate variability, resulting in large flood and drought damages.

Climatic and non-climatic factors, such as population growth and damage potential, will exacerbate these problems in the future. As a first step, improved incorporation of information about current climate variability into water-related management would assist countries towards adaptation to longer-term climate change impacts.

The combined and interacting forces of climate change and socio-economic drivers result in a continuously increasing demand for finite water resources for which there are no substitutes. When water resources of acceptable quality can no longer be provided in sustainable quantities, the outcome can lead to overexploitation of aquatic ecosystems. The ultimate losers are the exploited aquatic ecosystems and the organisms (including humans) dependent on them for survival and well-being.

Investment in water

Investment in water is an inseparable part of sustainable economic development. Climate change is one of a number of serious threats that have to be met by global society in coming decades. Policies and practices for mitigating climate change or adapting to it will have impacts on water resources, and how we manage water can affect the climate. Such adaptation measures must address several fundamental aspects: food, energy, environment, as well as overall economic development. They deserve top priority and commensurate funding.

There is clear evidence of a relationship between climate variability and economic performance in countries in which agriculture is a large share of GDP, as in Ethiopia and Tanzania.[3] Evidence further shows the direct relation between macroeconomic returns to investments in water management, and conversely, the costs of failures to invest. Environmental degradation from water pollution and excessive withdrawals also has negative economic impacts. For example, the damage cost of environmental degradation in the Middle East and North Africa has been estimated at some US$9 billion a year, or 2.1%–7.4% of GDP. Industrial countries are learning the enormous costs associated with restoring essential ecosystems. In the United States the costs have been estimated at more than $60 billion and continue to rise as more becomes known.

Conversely, the World Health Organization (WHO) estimates potential socio-economic returns of between US$3-$34, depending on the region and technology, for each $1 invested in safe drinking water and basic sanitation. There is a strong case that improved coverage of drinking water and sanitation contributes to economic growth.

Supply augmentation

Supply augmentation is typically constrained by the availability of storage sites, social and environmental costs, and the rising financial cost of water. With needs outstripping available stocks in many basins, transfers between basins have become more frequent. Amman, Athens, Bangkok, Kathmandu, Los Angeles and Mexico City are procuring water further afield. The massive transfer of water now under way in China (from the Yangtze River to the Yellow River) is being emulated in Brazil, India, Jordan and Thailand. While this trend is likely to continue, its potential will gradually be exhausted and its costs will spiral upwards. Other small-scale options, such as farm ponds in Asia or wells, have also been widely developed. Desalination is an option in specific locations (islands and coastal cities), but its cost is likely to remain high (though it is decreasing) and its use limited to urban supply. Other nonconventional sources of supply include wastewater, secondary sources (such as treated irrigation drainage) and the mining of fossil (non-renewable) aquifers.

Because of reuse of water in basins and users' adjustments to scarcity, fully developed basins or aquifers tend to have much less 'slack' than is often thought, and the potential for net water savings at the basin level is often overstated. When limits are reached and improved efficiency and demand management possibilities are exhausted, there are often no win-win solutions to meet additional demands; rather, resources must be reallocated from one source to another. These demand management options are discussed in more detail in the following section. Countries rarely resort to all three options at once, unless pressure over the resource is severe, as in Tunisia.

Integration of adaptation strategies

As highlighted in preceding sections, water resource management clearly impacts many other policy areas, for example energy, health, food security and nature conservation. Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors. Low-income countries and regions are likely to remain vulnerable over the medium term, with fewer options than high-income countries for adapting to climate change. Therefore, adaptation strategies should be designed in the context of development, environment and health policies.

The unpredictability of future water resources and pattern of distribution should not be an excuse for lack of action and strategic planning today.

The WWDR-3 contends that planning for future water resources often tends to prioritize the supply side of water rather than the demand side, thereby seriously undermining diminishing non-renewal water reserves, such as aquifers.

So far in the National Adaptation Programmes of Actions (NAPAs) prepared by the LDCs, there is a heavy bias towards supply-side interventions. It will be important for the success of adaptation strategies to strike the right balance between demand- and supply-side measures. Although supply-side measures have greater political attraction and can attract aid funding, demand management is vital to promote long-term sustainability.

Urgency of action

It is vital to address these major challenges now, rather than in the future, and to assist policy makers, practitioners and experts to map out strategies that can be implemented in the present. It is important to ensure that vulnerable populations are given the tools to build resilience that prepares them for coping with challenges today and in the future. For example, there needs to be better management of rainwater, soil moisture and supplemental irrigation. This will have strong impacts on poverty, since the farmers concerned are typically among the poorest, and are highly vulnerable to climatic variability. The increasing use of 'climate knowledge' to better understand the effects of climate variability and its socioeconomic impact, in which water is implicated, will also contribute to better adaptation strategies.

3 See Figure 5.2 in WWDR-3, 2009: 'GDP growth tracks rainfall variability in Ethiopia (1983–2000) and Tanzania (1989–1999), page 70.

Technology

Developing countries will depend on technology advances and transfers in their efforts to mitigate and adapt to climate change. According to the United Nations Framework Convention on Climate Change (UNFCCC), most technologies for adapting to climate change are already available in developing countries. Where they are not, the situation will call for the removal of obstacles and facilitation of technology transfer, and for more cooperation on research and development.

Combined with improved technology for monitoring, collecting and analyzing information, these developments should lead to improvements in warning systems for floods and droughts and other major water-related events. If these can be combined with hazard mitigation strategies involving all levels of affected communities, there are enormous opportunities to avoid loss of human life and economic damages.

Africa illustrates the situation in stark terms. Typical problems include low quality and quantity of basic equipment; poor technology; few laboratories for recalibrating equipment; inadequately trained personnel at both professional and technician levels; and insufficient funding and capital to sustain current operations or acquire new technologies. These technical challenges are compounded by the reluctance of countries to exchange data freely.

3 Responses to climate change must focus on water

Climate change, especially its implications for scarce water resources, is a matter of collective security in a fragile and increasingly interdependent world. At a 2007 United Nations (UN) Security Council debate on the impact of climate change on peace and security, UN Secretary-General Ban Ki-moon noted that climate change has implications for peace and security, as well as serious implications for the environment, societies and economies. In particular, he stressed that this is especially the case 'in vulnerable regions that face multiple stresses at the same time – pre-existing conflict, poverty and unequal access to resources, weak institutions, food insecurity and incidence of diseases such as HIV/AIDS'. 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. In Africa alone, by 2020, 75–250 million people may be exposed to increased water stress due to climate change (WWDR-3, page 19).

Adverse changes in internal, interjurisdictional and transboundary waters can put food, social, health, economic, political and military security at risk. Some fragile states have experienced widespread conflict that has resulted in the destruction of economic infrastructure. The vulnerability of affected populations is worsened by the state's loss of control over the forces of law and order and ultimately by its loss of political legitimacy.

Investing in water systems and services is an opportunity to counter these destabilizing forces. Widespread conflict in some fragile states has destroyed much of their social and economic infrastructure. Restoring this, and renewing their institutional capacity, can help to set post-conflict nations on a path to recovery. For example, the rehabilitation of damaged irrigation infrastructure and expansion of water supply and sanitation was a key feature of the 2006 Somali Rehabilitation and Reconstruction Plan. Rebuilding after major natural disasters is also an opportunity to address long-standing infrastructure deficits.

3a Addressing water drivers is an inescapable part of reducing vulnerability to climate change and building resilience for adaptation

One of the most pressing challenges that climate change brings is the vulnerability of populations, especially the poor among them, to the impacts of extreme events such as floods, storm surges and droughts. The rural poor, usually the most vulnerable and the most dependent on reliable environmental resources, represent about half of the world's population today, or 3.3 billion people (WWDR-3, page 31). While trends indicate that by 2030, urban dwellers will make up about 60% of the world's population, a large proportion of the other 40% will continue to rely on subsistence and rainfed agriculture for their livelihoods. Climate change is likely to intensify existing pressures, increasing risk, vulnerability and uncertainty. Over the longer term, incremental climate change will impinge on decisions about food security, energy security and land use, all with implications for the management of water resources and environmental sustainability.

The number of countries and regions without enough water to produce their food is rising as populations increase. Meeting water needs during dry seasons and ensuring security of supply require water storage. Climate change will intensify climate irregularity, so that more storage will be needed to ensure the same level of security. More water will have to be kept in reservoirs as reserves for dry spells, leaving less for everyday use. But this increased need for storage is occurring at a time when pressure from users is forcing water managers to take risks and reduce carryover stocks. Many regions are not yet taking the need to store more water into account, resulting in a growing frequency of local crises during extreme drought.

While in many developed countries water storage at a level of 70%–90% ensures reliable sources of water for irrigation, water supply and hydropower, as well as a buffer for flood management, less developed countries, such as those in Africa, for example, store as little as 4% of annual renewable flows, risking serious vulnerabilities in the short and longer term.

Developing countries need support of all kinds, including financial, to improve climatic adaptation, which affects development at many levels. In Africa, the impacts of climate change are expected to range from increased energy shortages, reduced agricultural production, worsening food security and malnutrition to the increasing spread of disease, more humanitarian emergencies, growing migratory pressures and increased risks of conflict over scarce land and water resources. Finance for adaptation should be augmented and made available for programmes in all sectors where this is likely to be required.

3b There has to be a balance between mitigation and adaptation strategies so that win–win solutions can be realized

There is an urgent need to mitigate the pressures on climate change, but meanwhile there is an even more urgent need to adapt to changes that are already under way. Adaptation measures must be taken in several crucial areas: food, energy, the environment and economic development: all deserve top priority and commensurate funding.

The intergovernmental response has focused primarily on mitigation of climate change, embracing wide-ranging measures including reducing greenhouse gas emissions, developing clean technologies and protecting forests. But although these measures may slow climate change, they will not halt or reverse it, and it will be two generations before they begin to have an effect. Even if successful, we face a considerably changed future climate.

People must be protected from the consequences of global climate change through adaptation measures.

Decisions and policies for mitigation (reducing greenhouse gas emissions, applying clean technologies and protecting forests) and adaptation (such as expansion of rain-water storage and water conservation practices) can have profound consequences on water supply and demand. Climate mitigation measures are not always beneficial for water resources, while some water management policies can even increase greenhouse gas emissions.

For example, many developed countries are shifting to 'clean' energy sources and away from thermal energy plants based on fossil fuels. But there is evidence that hydroelectric stations can generate large volumes of greenhouse gases released from sediment and decaying organic matter at the bottom of reservoirs. Even marginal land, for example that used by pastoralists and subsistence agriculturalists in Africa, is being targeted by developed countries for biofuel production. Water resource implications, as well as climate change impacts on these fragile ecosystems, must be fully taken into account so that win–win scenarios can be developed.

The First African Water Week, convened in Tunis in March 2008, opened with a call for greater efforts to ensure water security nationally and regionally. Donald Kaberuka, president of the African Development Bank Group, emphasized that 'it is no longer acceptable that the African continent continues to utilize only 4% of its water resources, when a huge proportion of the people do not have access to safe water, and when large populations are faced with frequent floods and drought, in addition to food and energy shortages. Action is urgently needed' (WWDR-3, page 11).

3c Agriculture is a primary area for development of adaptation strategies

Climate change is expected to alter hydrologic regimes (the pattern of precipitation, runoff, infiltration and evaporation affecting a water body) and the availability of freshwater, which will affect both rainfed and irrigated agriculture. There is increasing likelihood of reduced precipitation in semi-arid areas, more variable rainfall distribution, more frequent extreme events and rising temperatures, especially in low latitudes. A severe reduction in river runoff and aquifer recharge is expected in the Mediterranean basin and in the semi-arid areas of Southern Africa, Australia and the Americas, affecting the availability of water for all uses.

Agriculture is by far the largest consumer of freshwater. Globally, about 70% of freshwater withdrawals go to irrigated farming. Water scarcity may limit food production and supply, putting pressure on food prices and increasing countries' dependence on food imports. The number of countries and regions without enough water to produce their food is rising as populations increase.

Agriculture has a complex relationship with climate change. On the one hand, it adds to global warming through emissions of methane and other gases into the atmosphere. To mitigate this, changes in land use practices (management of cropland and grazing land) are considered to be the best options. On the other hand, agriculture is also likely to be seriously affected by climate change in different ways, depending on geographical and other factors. Large areas of croplands, in particular in semi-arid zones, will need to adapt to new conditions with lower precipitation.

The projected increase in the frequency of droughts and floods will affect the yield of crops and livestock. Though its net effect on food production at the global level is uncertain, climate change will alter the distribution of agricultural potential. Most of the increase in cereal production will be concentrated in the Northern Hemisphere, while local production could be affected, especially in subsistence sectors at low latitudes. Several densely populated farming systems in developing countries are at risk. A combination of reduced base flows from rivers, increased flooding and rising sea levels is expected to damage highly productive irrigated systems that help maintain the stability of cereal production. These production threats will be more significant in alluvial plains dependent on glacier melt (e.g. Colorado, or Punjab) and, in particular, in lowland deltas (the Ganges and Nile).

In key areas of food insecurity dominated by rainfed agriculture (sub-Saharan Africa and peninsular India, in particular), the expected reductions in production may have multiple impacts including loss of livelihoods and displacement of rural populations. This will accentuate demand in global markets and put further pressure on irrigated production. In large irrigation systems that rely on high mountain glaciers for water, such as the Andes, Himalayas and Rocky Mountains, temperature changes will cause high runoff periods to shift to earlier in the spring, when irrigation water demand is still low. Such changes could incite demand for new water-control infrastructure to compensate for changes in river runoff. Elsewhere, current farming and cropping systems may become unsustainable.

Adjusting to climate change is one amongst several major challenges facing agriculture in the coming decades. Other challenges include producing enough food and soft commodities to satisfy the growth of global populations, sharing scarce water and land with other growing use sectors, and acknowledging the ecological and environmental need for water supply. The use of water is also being judged increasingly by equity and efficiency criteria. In short, major reforms and changes in farmer behaviour are called for.

Technological improvements can occur at all levels and affect all types of irrigation systems. These are not necessarily new, expensive or sophisticated options, but rather ones that are appropriate to needs and respond to actual demands. They should also match the capacity of system managers and farmers, and the resources available for proper operation and maintenance. Technological innovation is likely in three broad categories:

1. At the irrigation system level: water level, flow control and storage management within surface irrigation systems on all scales.
2. On the farm: storage, reuse, water lifting (manual and mechanical) and precision application technologies, such as overhead sprinklers and localized irrigation.
3. Across sectors: multiple-use systems in rural areas and urban agriculture with wastewater.

The situation can be remedied in many developing countries by investing in water infrastructure and by developing markets, credit, agricultural technology and extension services. Making national water policies more coherent is the basic aim of Integrated Water Resources Management (IWRM), a leading paradigm used by those involved in determining water policy.

3d There exist a variety of no-regrets solutions that will help address current and possible future water-related vulnerability and generate multiplied development benefits, regardless of climate scenarios

The threat of climate change has led to many developments in the simulation of atmospheric processes, improving the accuracy of climate and weather forecasts. Combined with improved technology for monitoring, collecting and analyzing information, these developments should lead to improvements in warning systems for floods and droughts and other major water-related events. If these can be combined with hazard mitigation strategies involving all levels of affected communities, there are enormous opportunities to avoid loss of human life and economic damages. Other examples of potential hazards becoming opportunities include using increased runoff from glacial melting to develop more reliable water reserves. However, this solution will only be temporary and viable as long as the glaciers have not melted completely. In other countries, potential for increasing the reliability of water supplies exists through the use of flood water storage to increase the reliability and to improve floodplain management and planning.

Approaches to incorporating climate change information in decision-making can be either direct or indirect. *Direct approaches* incorporate climate change information into decision-making – for example, climate scientists interacting with partnering utilities to find space and time scales appropriate for adaptations to reduce the risk of climate extremes. *Indirect approaches* involve potentially affected people in studies of the readiness of societies to adapt to climate change. Although the indirect approach has dominated to date, the direct approach is likely to begin to predominate as water managers and decision-makers become more serious about adaptation to climate change.

Responses to the challenges of climate change are likely to be specific for each country or national region. The NAPAs under the UNFCCC are still in their early phases and much remains to be done, especially in the least developed countries, to coordinate climate- and water-related policies and actions. Bhutan is one example of a country that has coordinated its national water and climate change adaptation policies to meet short- and long-term threats of glacier lake outburst floods resulting from climate change-induced glacier melting. Another good example for policy integration is Tunisia.

High-income countries are experiencing water management problems that are very different from those of poor countries. While high-income countries can afford to pay more attention to the environment and to long-term water system sustainability, developing countries prioritize eliminating poverty and raising the overall level of health and well-being, sometimes at the expense of environmental sustainability. Conflict situations regarding water usage between agriculture and other demands will create additional challenges for water managers and policy makers.

Given the uncertainties about climate change, decisions on current problems should leave the way open for future options. No-regrets strategies – actions that would significantly reduce the adverse impacts of change but would not cause harm if projections of impacts of change are wrong – are important in responding to climate change. In contrast, failure to act carries risks because the situation may deteriorate if no action is taken.

Developed countries and developing countries must work together to identify socioeconomic priorities and to invest in and use water to power the engines of growth. They must break cycles of poverty while avoiding the harmful environmental and health consequences of unbridled development experienced in many developed countries. Cooperation between developed countries and developing countries can build mitigation, adaptation, avoidance and no-regret measures into decision-making, to avoid incurring the costs of neglected environmental management later.

It will be important to work toward reducing uncertainty, facilitate decision-making and accelerate investment by identifying the links between socioeconomic development, environmental sustainability, water management capacity and investments in water-related infrastructure and other sectors.

Options depend on social, economic and environmental conditions, the availability of water over space and time, and the threat of droughts and floods, all of which vary around the world. Where water is scarce, the challenge is to select the development path that attains the best social, economic and environmental outcomes. Such decisions shift the trade-offs away from water resources alone to broader concerns of environmental, economic and social benefits. Making decisions about water in this context can sometimes introduce inefficiencies in other development activities. For example, importing food rather than producing it domestically may permit water to be used for higher value outputs, but many farmers will then need to find other ways to earn a living.

4 Proactive adaptation requires enabling policy conditions at all levels: national, regional and international

The imperatives of climate change have forced attention to critical issues of water resources management that need addressing, regardless of global warming. In this respect, climate change could be a blessing in disguise if it leads the more sustainable use of resources. Such management issues include improved observation networks, increased integration of groundwater and surface water supplies (including artificial recharge), improved early warning and forecasting systems for hazardous events, improved risk-based approaches to management, and raising community awareness of sustainable water use and individual responses to water-related hazards.

The decisions and policies that can be put in place today for mitigation (such as reducing greenhouse gas emissions, applying clean technologies and protecting forests) and adaptation (such as expansion of rainwater storage and water conservation practices) can have profound consequences for water supply and demand, both today and over the long term.

Public policy in response to global warming has so far been dominated by mitigation. WWDR-3 argues for a more judicious balance between mitigation and adaptation to a process of global warming that appears already well under way. To safeguard the integrity of our water resources, governments should commit to much more support for adaptation measures and increases in funding for these. Funding for adaptation, part of which is derived from the proceeds of the Clean Development Mechanism (CDM), should be increased for all water-related sectors where adaptation is called for. Adaptation is a more urgent perspective for African countries to take than mitigation initiatives. It is widely accepted that Africa, even now, has much less storage relative to its needs for flood and drought alleviation than other regions. This need will increase if, as expected, climatic conditions become more unstable in future. Africa also has more scope than elsewhere to expand its irrigated area, though upgrading its rainfed farming systems will also be vital to its adjustment.

Water resources must be viewed holistically, considering both their natural state and the need to balance competing demands – domestic, agricultural, industrial and environmental – to ensure sustainability. Sustainable management of water resources requires systemic, integrated decision-making that recognizes the interdependence of decisions; scenarios are particularly helpful for this purpose.

Scenarios – which are sets of alternative futures – differ from forecasts, which are individual interpretations of a most probable future based on extrapolation of the best available information. Scenarios are not forecasts. Because the real world is so complex, forecasts are often wrong, especially those involving a time horizon of 20 years or more. Scenarios provide a means of looking beyond the water sector in search for an adequate causal understanding of different water issues. Proper scenario development and their use can contribute to several goals in the pursuit of sustainable water resources.

The need for a long-term view

A long-term view of water for sustainable development requires taking into account the slow unfolding of some hydrologic, environmental and social processes and allowing time for waterworks investments and water mitigation schemes to yield results.

The need for perspective

Qualitative scenarios provide guidance, perspective and context for computer models and sectoral studies, while models and studies provide consistency and feasibility checks for some elements of water scenarios, as well as numerical estimates of the modeled variables. Further, global scenarios provide a context for scenarios on a smaller geographic scale (local, watershed, national or regional). Many important changes in a river basin are determined by factors from outside the study area.

The need to make decisions in a context of high uncertainty

Decision-makers in the water sector must often address water management issues against a background of rapidly changing environmental conditions and increasing uncertainty. The uncertainty results from both a limited understanding of human and ecological processes and the intrinsic indeterminism of complex dynamic systems. Water resources futures depend on future human choices, which are unknown.

The need to include non-quantifiable factors

The world's water system includes, and is influenced by, many factors that are difficult to quantify (such as cultural and political variables and processes), as well as factors that can be quantified and modeled mathematically (such as hydrologic and climatological dynamics and economic factors). Qualitative scenario analyses can provide insight into these factors that simulation models cannot.

The need for integration and breadth

Water resources must be viewed holistically, considering both their natural state and the need to balance competing demands – domestic, agricultural, industrial and environmental – to ensure sustainability. Decisions on land use can affect the availability and condition of water resources, while decisions about water resources can also affect the environment and land use. Decisions about economic and social futures can affect hydrology and ecosystems. Meanwhile, decisions at the international, national and local levels are all connected. Sustainable management of water resources requires systemic, integrated decision-making that recognizes the interdependence of decisions; scenarios are particularly helpful for this purpose.

The need to organize understanding for decision-making

Decision-makers may have difficulty identifying the elements from different studies that are most relevant for their decisions. Scenarios are developed with decision-making in mind. They are constructed to focus attention on causal processes and decision points, the unfolding of alternatives and the branching points at which human actions can significantly affect the future.

The need for an arena for conversation among water stakeholders

Scenarios provide common frameworks for mapping and highlighting critical concerns of diverse stakeholders and identifying alternatives – setting the stage for discussions, debates and negotiation.

4a At national level, water governance must be expanded to and integrated with non-water sectors; access to technology, science and information should be increased for sound planning; development efforts should be checked for what could be maladaptations with regards to water

The best mix of responses to a country's development objectives and policy priorities to meet its water challenges depends on the availability of water in space and in time and the country's technical, financial, institutional and human capacities – its culture, political and regulatory frameworks, and markets.

Within government, water use and management are ultimately decided by the interaction of decision-makers in the main socioeconomic sectors – health, education, agriculture, housing, industry, energy, economic development and environment.

Among the decisions that affect water the most are those relating to how a country meets its objectives for energy and food security, employment, disaster preparedness, environmental sustainability and other societal goals. These decisions are made in broader political frameworks and not by water managers, who subsequently deal with their implications for water and with other outcomes that touch on water.

Many countries face multiple challenges but have limited financial and natural resources and implementation capacities. Countries need to fully use synergy opportunities and to make trade-offs and difficult decisions on how to allocate water among uses and users to protect their water supply. To achieve results, many actors need to participate in these decisions.

For many years action on water that could deliver benefits to the poor lacked government frameworks that prioritized poverty reduction and mobilization of financing. Today, poverty reduction strategies still offer only the prospect of aligning action on water with poverty reduction, as few current poverty reduction strategies give anything but superficial attention to action on water.

As water scarcity increases so does the need for financial investment to adapt to water supply variabilities, competition between different water usage demands is a growing concern. Competition for water and weaknesses in managing water to meet the needs of society and the environment call for enhanced societal responses through improved water resource management, better legislation and more effective and transparent allocation mechanisms.

Challenges include wise planning for water resources; evaluation of availability and needs in a watershed; possible reallocation or storage expansion in existing reservoirs; more emphasis on water demand management; a better balance between equity and efficiency in water use; inadequate legislative and institutional frameworks; and the rising financial burden of ageing infrastructures.

Sectoral water resource strategies for adaptation to climate change that do not take holistic integrated approaches, or competition between different sectors can lead to maladaptation that, in turn, may exacerbate current problems or give rise to future issues. Maladaption is interpreted as actions or processes that increase vulnerability to climate change-related hazards. Maladaptive actions and processes often include planned development policies and measures that deliver short-term gains or economic benefits but lead to exacerbated vulnerability in the medium to long-term (UNDP definition).

A growing number of countries and cities are including water-related adaptation into their planning, policy and institutional response to such predicted impacts as rising sea-levels, more frequent droughts and increased precipitation.

Multisectoral water mainstreaming is essential for incorporating climate change risks and adaptation into developing strategies. They apply at different levels:

1. **National policies, programmes and priorities**
   Information about climate-related risk, vulnerability and options for adaptation must be incorporated into planning and decision-making in key sectors, such as agriculture, water, health, disaster risk management and coastal development. This information must also be considered in existing national assessments and action plans, including poverty reduction strategies and priorities.

2. **Development agency programmes and policies**
   Plans and priorities identified in development cooperation frameworks must incorporate climate change impacts and vulnerability information to support development outcomes (e.g., UNDP Country Cooperation Framework, UN Common Country Assessment and UN Development Assistance Framework).

   Ideally, integration should become a systematic process rather than a one-off process of utilizing climate information in decisions (UNDP draft working definition).

The integrated approach to dealing with water scarcity and sectoral competition is illustrated in Figure 9.2 of the WWDR-3 (see opposite).

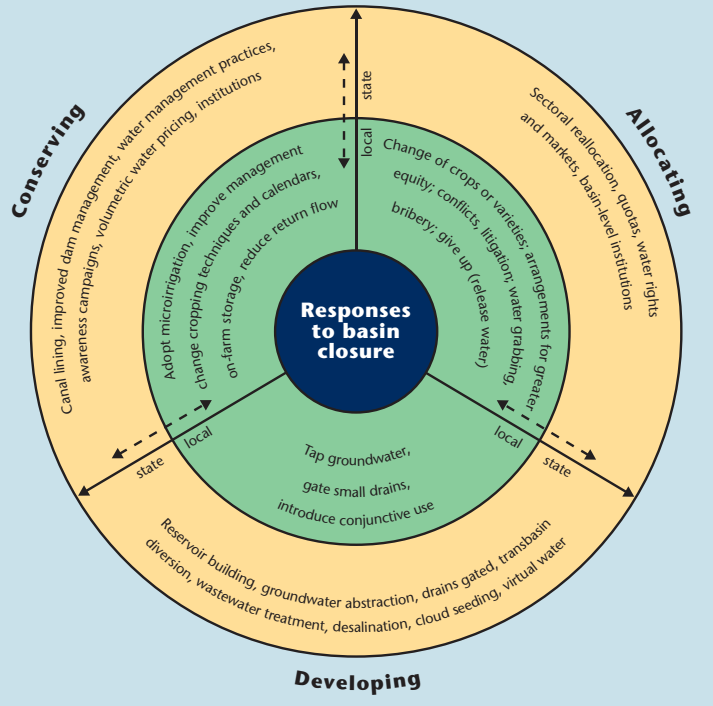
Conflicts about water can occur at all scales. Local-level conflicts are commonplace in irrigation systems, where farmers vie for limited resources. In Northern Thailand, for example, low flows in the dry season are diverted by upland farmers to irrigate their orchards, where use of pesticides sometimes leads to the pollution of streams. Conflicts also occur at the scale of large national river basins (multistate Indian rivers such as the Cauvery and the Krishna) or transnational river basins (the Jordan and the Nile). While conflict resolution mechanisms and adequate modes of governance will differ with scale, the nested nature of these scales also means that the modes of governance will have to be consistent and interrelated.

Sectoral conflicts oppose users from different sectors (domestic, hydropower, irrigation, industries, recreation and so on), including ecosystems, those sustainability depends on environmental flows. These conflicts are both economic (the return per cubic metre differs greatly across these uses) and political (the social importance and the political clout of each sector also varies).

Perhaps the most common conflict is between agriculture and cities. Half the world's population lives in cities – and this share is increasing – while agriculture is generally the largest user of water. Moving water from agriculture to uses with higher economic value is frequently proposed, for several reasons. Agriculture gets by far the largest share of diverted water resources and also consumes the most water through plant evapo-transpiration. Cities are also thirsty. The value-added of water in non-agricultural sectors is usually far higher than in agriculture. This apparent misallocation is often attributed to government failure to distribute water rationally. On the other hand, much of the water used for agriculture ultimately serves to feed the world's ever-growing urban populations.

Dealing with risk and uncertainty has long been a routine challenge for water resource managers and policy-makers across sectors and the world. However, issues like climate change and demographic dynamics have made the risks greater and the task more complex. Risk management is now much more important – indeed essential – to analysis and decision-making.

Figure 9.2 **Three types of response to water scarcity and competition**



Source: Based on Comprehensive Assessment of Water Management in Agriculture 2007.

UN World Water Development Report 3: Water in a Changing World, Figure 9.2 (page 154)

Risk management encompasses more than managing extremes such as floods and droughts. It entails the use of a structured approach to manage uncertainty regarding these events. Decision-makers must take into account multiple uncertainties, including those associated with limited or low-quality data and information and the inherent unpredictability of climate and other environmental factors.

A promising approach for dealing with climate risk is to integrate management of current climate variability and extremes with measures towards adaptation to climate change.

The responses to increased competition for water are supply augmentation, conservation and reallocation (WWDR-3, Figure 9.2). The most conventional response is to develop new resources. For the state, this typically means building new reservoirs or desalination plants or improving interbasin transfer. For users, this means more wells or farm ponds or gating drains to store water. Conserving water includes increasing the efficiency of use by reducing losses. Changes in allocation to ease competition or to maximize water use are based on economic, social, environmental or other criteria. Augmentation is a supply management strategy, while conservation and reallocation are demand management strategies, roughly defined as 'doing better with what we have.'

Water managers need reliable information about the availability and use of water in all its aspects, which the WWDR-3 aims to provide. Although the problems it describes are not new, and have been expressed before, they have been gathering force. The global crises that we now confront – in energy, food, climate change, environment and economic development – all involve water in different ways.

There are many practical examples of solutions within the water domain. Some options show particular promise. Preparing institutions to deal with current and future challenges requires support for institutional development through such reforms as decentralization, stakeholder participation and transparency, increased corporatization where feasible and fair, partnerships and coordination (public-private, public-public, public-civil society), and new administrative systems based on shared benefits of water, including when water crosses borders. Decision-makers need to consider the influence of water law, both formal and customary, including regulations in other sectors that influence the management of water resources.

Decision-making is improved by consulting with stakeholders and ensuring accountability in planning, implementation and management as well as building trust within the water and related sectors and fighting corruption and mismanagement. Strengthening organization structures and improving the operating efficiency of water supply utilities will help to improve service quality and increase the coverage and density of connections, while also boosting revenues and creating a more viable financial base to attract further investment. Innovation and research are critical for developing appropriate solutions. And greater institutional capacity and human capacity are needed, both within the water domain and in areas or sectors outside the water domain. Capacity development can occur through traditional forms of education, on-the-job training, e-learning, public awareness raising, knowledge management and professional networks. Sound management accountability and good governance within the water sector contribute to creating a favourable investment climate.

Identifying trade-offs and synergies between water and other policy sectors can enhance policy impacts in all sectors and avoid some adverse effects on water. Because governments, civil society and business leaders make decisions every day that can affect water, it is important to identify where such decisions can also lead to improvements in water sector management and in water sector and environmental services.

Examples of win-win situations abound – whether created by governments, communities or businesses – that point to promoting deliberate cooperation between water and non-water actors and integrating water issues into external decisions. International organizations, notably the UN system, can provide support and expertise to governments, help civil society build capacity and catalyze leadership in the private sector.

Decision-making on water requires seeking synergies and selecting appropriate tradeoffs. It also requires distinguishing between short-term 'fire-fighting' – responding to the urgent issues of the day – and long-term strategic development. Developing multipurpose water schemes and reusing water wherever feasible can lessen the need for trade-offs by enabling the same volumes of scarce water to deliver multiple outcomes. The donor community can incorporate water into the broader frameworks of development aid and focus assistance on areas where it is needed most – in sub-Saharan Africa, in Asian and Latin American slums and in states recovering from conflict. Recent G-8 efforts in this direction are promising.

A nation's water resources are used and managed most effectively when they are linked to broader development objectives. What are the objectives, for example, for feeding the population, for providing power for industry, commerce and households, for job creation and incomes, and for child education and health? What are the relations between these objectives, and water and water systems? How should water be managed to achieve these objectives?

4b At regional level, collaborative water management for shared surface and groundwater should be emphasized; there are numerous models for sharing water that provide equity as well as rational management

Improved networks for hydrologic data collection and monitoring can minimize uncertainties in forecasting and lessen decision-making risk in several ways. Networks can provide unrestricted access to better-quality information from improved measurements (in terms of quantity, quality and timeliness) and techniques and lead to improved model structures based on a better understanding of physical processes and better mathematical representation and use of available information during model identification and calibration.

The level of uncertainty for assessment and forecasting varies, but is generally high in subtropical, tropical, polar and mountainous regions. Networks also tend to be weak in developing countries, especially the least developed.

Despite its importance for the integrated management of water quantity and quality and for understanding water-related health hazards, no comprehensive information exists on the regional or global extent of wastewater generation and treatment or of receiving water quality. Even at the national level such information is either inconsistently gathered or unavailable – partly because of ill-defined data collection responsibilities that rest with a multitude of national organizations and commercial entities which rarely share their information.

A needs-based approach should form the basis of any data-sharing policy. Many data-sharing protocols and agreements already exist at the national, regional and global levels. In transboundary basins, where lower riparian countries have a disproportionally larger benefit from upstream observations, such agreements could require downstream users to contribute more to the maintenance and operation of upstream stations.

Managing the world's water resources requires reliable data on the state of the resource and how it is changing in response to external drivers such as climate change and water and land use. There is little sharing of hydrologic data, due largely to policy and security issues; limited access to data; lack of agreed protocols for sharing; and commercial considerations. This hampers regional and global projects that rely on shared datasets for scientific and applications-oriented purposes, such as forecasting, seasonal regional hydrologic outlooks, disaster warning and prevention, and integrated water resources management in transboundary basins.

Although water is often described as a 'gift of nature', harnessing and managing it for the wide variety of human and ecological needs entail financial costs. Governments still have only three basic means of financing water resources development: tariffs, taxes and transfers through external aid and philanthropy.

Regional cooperation and commitment to tackle climate change impacts, mitigation and adaptation are of vital importance. The African Heads of State Declaration on water as a key to sustainable development is a prime example of policy level understanding of the challenges at the highest level (see Box 1.1 on page 7 of the WWDR-3, reproduced below).

Box 1.1 Commitment of African heads of state to water as a key to sustainable development

WE, the Heads of State and Government of the African Union, meeting at the 11th Ordinary Session of our Assembly in Sharm el-Sheikh, Arab Republic of Egypt, from 30 June to 1 July 2008,

Recognizing the importance of water and sanitation for social, economic and environmental development of our countries and Continent; . . .

Recognizing that water is and must remain a key to sustainable development in Africa and that water supply and sanitation are prerequisites for Africa's human capital development;

Concerned that there is an underutilization and uneven sharing of water resources in Africa, and that remains a growing challenge in the achievement of food and energy securities. . . .

WE COMMIT OURSELVES TO:

(a) *Increase* our efforts to implement our past declarations related to water and sanitation.

(b) *Raise* the profile of sanitation by addressing the gaps in the context of the 2008 eThekwini Ministerial Declaration on sanitation in Africa adopted by [the African Ministers Council on Water].

(c) *Address* issues pertaining to agricultural water use for food security as provided for in the Ministerial Declaration and outcomes of the first African Water Week.

And particularly;

(d) *Develop and/or update* national water management policies, regulatory frameworks, and programmes, and prepare national strategies and action plans for achieving the MDG targets for water and sanitation over the next seven (7) years;

(e) *Create* conducive environment to enhance the effective engagement of local authorities and the private sector;

(f) *Ensure* the equitable and sustainable use, as well as promote integrated management and development, of national and shared water resources in Africa;

(g) *Build* institutional and human resources capacity at all levels including the decentralized local government level for programme implementation, enhance information and knowledge management as well as strengthen monitoring and evaluation;

(h) *Put in place* adaptation measures to improve the resilience of our countries to the increasing threat of climate change and variability to our water resources and our capacity to meet the water and sanitation targets;

(i) *Significantly increase* domestic financial resources allocated for implementing national and regional water and sanitation development activities and call upon Ministers of water and finance to develop appropriate investment plans;

(j) *Develop* local financial instruments and markets for investments in the water and sanitation sectors;
(k) *Mobilize* increased donor and other financing for the water and sanitation initiatives. . . .

Source: African Union 2008.

UN World Water Development Report 3: Water in a Changing World, Box 1.1 (page 7)

4c At international and global level, financing for water-related investments should be increased, including for infrastructure, technology, and data collection and dissemination

The international community also has to balance investing for tomorrow's likely problems of greater climate variability and global warming against investing for today's problems of climate variability to prevent losses from droughts and floods. While both are vital, focusing on today's problems can also create greater resilience for dealing with tomorrow's problems. The world faces major choices in meeting the challenge of climate change and its potential environmental and socioeconomic impacts. Public policy, so far dominated by mitigation, could benefit from a better balance between mitigation and adaptation. Figure 1.4 from the WWDR-3 illustrates how water-related investments are financed (see below).

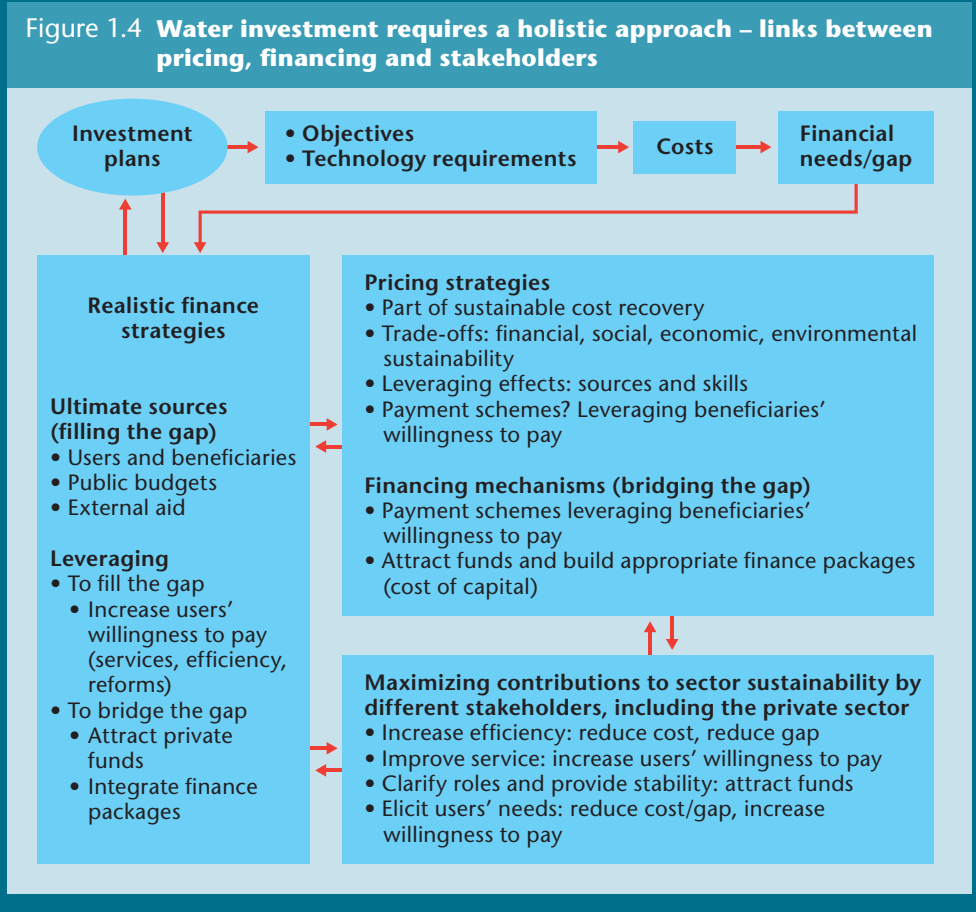
Water management choices should emerge from informed consultation and negotiation on the costs and benefits of all options after considering basin interconnectedness, relationships between land and water resources, and the consistency and coherence of decisions with other government policies.

Growth and changes in the global economy are having far-reaching impacts on water resources and their use. Growing international trade in goods and services can aggravate water stress in some countries while relieving it in others through flows of 'virtual water' (water embedded in products and used in their production, particularly in the form of imported agricultural commodities).

Policy-makers need to make political decisions on socially and environmentally acceptable trade-offs among different objectives, and on who bears the costs of such compromise.

UN World Water Development Report 3: Water in a Changing World, Figure 1.4 (page 9)

Figure 1.4 **Water investment requires a holistic approach – links between pricing, financing and stakeholders**



4d At regional level, collaborative water management for shared surface and groundwater should be emphasized; there are numerous models for sharing water that provide equity as well as rational management

Commitments have been made by the donor community to increase assistance to the broad water sector, but this has led mainly to an increase in allocations for water supply and sanitation in dollar terms (although its share of total official development assistance has stagnated at 4%). The percentage of total aid allocated to the water sector remains below 6% and has been declining.

Worldwide, water observation networks provide incomplete and incompatible data on water quantity and quality for properly managing water resources and predicting future needs – and these networks are in jeopardy of further decline. Also, no comprehensive information exists on wastewater generation and treatment and receiving water quality on a regional or global scale.While new technologies based on satellite remote sensing and modelling present opportunities, their value is limited by our ability to ground truth and validate the simulated information.

Improving water resources management requires investments in monitoring and more efficient use of existing data, including traditional ground-based observations and newer satellite-based data products. Most countries, developed and developing, need to give greater attention and more resources to monitoring, observations and continual assessments of the status of water resources.

It is essential to take the cost of adapting to climate change into account at all levels and ensure sufficient resources are made available in particular to developing countries that often bear the most devastating impacts of climate change. Examples of estimates for the cost of adapting to climate change are provided in Box 5.1 of the WWDR-3 (see below).

Box 5.1 **The cost of adapting to climate change**

Estimates of the costs of climate change impacts vary because they depend on future greenhouse gas emissions, mitigation measures and assumptions about anthropogenic climate change itself and about how effectively countries will adapt to it. The following are some estimates of the costs of adaptation for developing countries:

- World Bank estimates of the additional costs to adapt or climate-proof new investments range from $9 to $41 billion a year. And a recent update by the United Nations Development Programme put the mid-range of the costs of adaptation at about $37 billion a year in 2015.
- The United Nations Framework Convention on Climate Change estimates additional investments for adaptation to climate change at $28-$67 billion and as high as $100 billion a year several decades from now. Estimates of the additional investments needed in water supply infrastructure in 2030 are $11 billion, 85% of it in developing countries.
- Oxfam estimates the current costs of adaptation to climate change for all developing countries at more than $50 billion a year.

While there is considerable debate about these estimates, they provide useful order-of-magnitude numbers for assessing resources available for adaptation. Current Global Environment Facility funds (about $160 million) are several orders of magnitude too little to meet these projected needs.

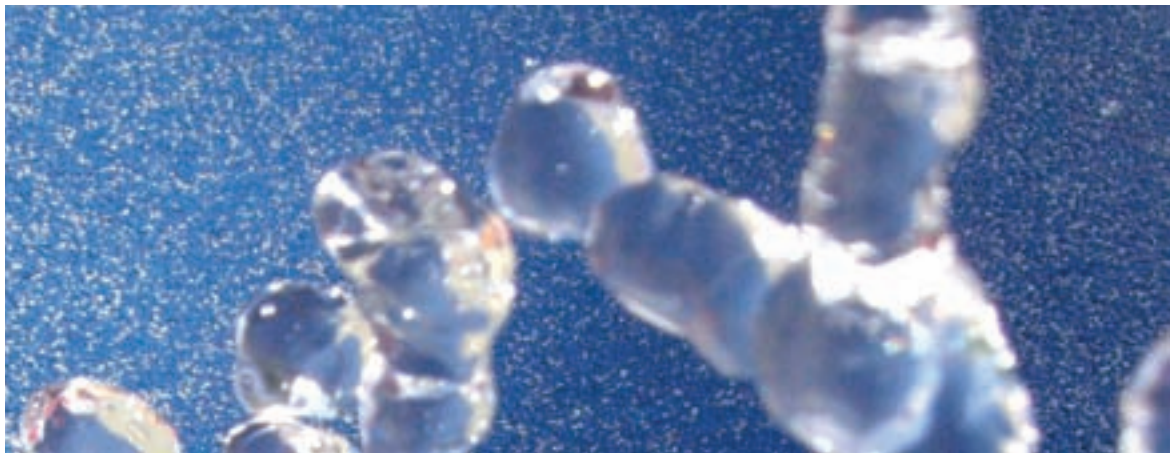
Source: World Bank 2006; UNDP 2007; UNFCCC 2007b; Oxfam 2007.

UN World Water Development Report 3: Water in a Changing World, Box 5.1 (page 71)

At the High-Level Event on the MDGs at the UN in September 2008, discussion focused on the need for new adaptation strategies and for climate-resilient national development plans, especially for the least developed countries: linkages between financing for development and international climate change financing were discussed. It was also agreed that all countries, including donor countries, the UN system and the Bretton Woods institutions, need to clarify the budgetary implications of adaptation; ensure that adequate finance mechanisms are in place; and help meet the additional costs that climate-resilient development will entail.

A number of specific recommendations affect all levels of policy and be summarized as follows:

- At the national, regional and global levels a minimum requirements analysis of long-term, multipurpose observational needs should be undertaken; a new requirement is climate-relevant observations, including those from pristine basins.
- Financing of hydrologic networks, including operation and maintenance, should be based on a multiple-source strategy rather than on the prevailing single-source, sector-specific funding arrangements.
- Integrated multiplatform network solutions that combine in-situ and space-based observations and that are affordable for developing countries should be promoted. This would increase the number of observations over space and time.
- Other hydrologic information – such as in-situ and remotely sensed soil moisture and meteorological data and information including precipitation, evaporation, humidity, temperature and wind fields – needs to be considered to complement hydrologic information and to enhance the information content of hydrologic data through integration in multivariate models and predictions.
- In data-sparse regions in particular, modelling approaches need to be mainstreamed to generate model-derived observation time series. A promising tool is the reconstruction of hydroclimatic data by downscaling. Datasets from the National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) for 1948–2007 are a widely used source. As observational gaps are often directly related to deficiencies in data transmission and communication, this could be overcome to a large degree by connecting offline operating stations to modern telecommunication systems to increase spatial and temporal availability of data from already existing stations. Making maximum use of existing hydrologic observations requires more effort to share hydrologic data and information on all levels, including transboundary river basins and shared aquifer systems.



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This Special Report presents an overview of messages on climate change from the World Water Development Report 3 (WWDR-3):

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African Union. 2008. *Sharm El-Sheikh Commitments for Accelerating the Achievement of Water and Sanitation Goals in Africa. Declaration I.* Assembly of the African Union, Eleventh Ordinary Session, 30 June-1 July, Sharm el-Sheikh, Egypt. www.africa-union.org/

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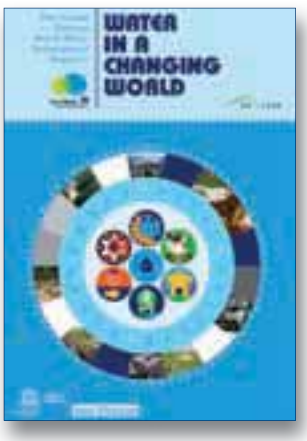
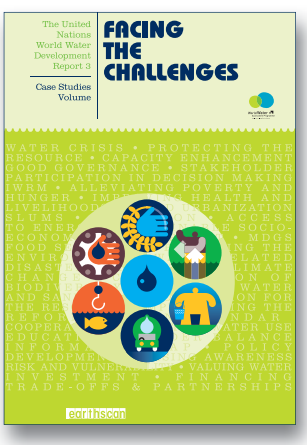
The United Nations World Water Development Report 3:
Water in a Changing World

This World Water Assessment Programme Special Report brings together messages on water and climate change from the *World Water Development Report 3: Water in a Changing World*, the foremost United Nations report on the state of the world's freshwater resources.



Coordinated by the World Water Assessment Programme, the *World Water Development Report* is a joint effort of the 26 United Nations agencies and entities that make up UN-Water, working in partnership with governments, international organizations, non-governmental organizations and other stakeholders. It offers a comprehensive review of the state of the world's freshwater resources and provides decision-makers with the tools to implement sustainable use of our water. The report, published every three years, represents a mechanism for monitoring changes in water resources and management and tracking progress towards achieving international development targets. it offers best practices as well as in-depth theoretical analyses to help stimulate ideas and actions for better stewardship in the water sector.



The third edition of the report, *Water in a Changing World* is presented together with a case-study volume, *Facing the Challenges*. Adopting the premise that local actions and on-the-groun insights are the starting point of a global strategy to improve management of the world's freshwater resources, these twenty case studies from around the world examine water challenges and differing managment approaches taken in response.

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A United Nations World Water Assessment Programme Special Report