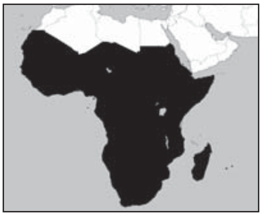

Adapting to climate change: water management for urban resilience

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ABSTRACT Global warming and related climate changes are likely to significantly increase the weather-related risks facing human settlements, including floods, water and power supply failures and associated economic collapse into "failed cities". Action to help poor urban communities adapt to become more resilient to possible change must therefore be initiated, although to date attention has focused on mitigation rather than adaptation. This paper considers the physical and financial implications for urban areas of the potential impacts of climate variability and change on water resources, illustrated by examples from sub-Saharan Africa, which is likely to be one of the most vulnerable and most affected regions. Water management, which will be particularly affected by climate change, could provide an opportunity to initiate structured adaptation responses. Adaptation costs in the sub-Saharan urban water sector are estimated at between 10 and 20 per cent of current overseas development assistance to the region. This paper suggests that additional funding should be made available in terms of the "polluter pays" principle, and should be channelled through government budgets rather than ring-fenced climate funds. This would help ensure that "climate proofing" is mainstreamed and would be in keeping with current trends in overseas development assistance reflected in the 2005 Paris Declaration on Aid Effectiveness.

KEYWORDS adaptation / aid effectiveness / climate change / dams / hydrology / sub-Saharan Africa / water

I. INTRODUCTION

It is anticipated that global warming and related climate changes, which are predicted to occur over the next century, will significantly increase the weather-related risks facing human settlements. However, while significant attention has been focused on actions to mitigate climate change, less has been done to adapt to a future that many believe is already beginning. Nor is it clear how such adaptation can be promoted most effectively.

At the World Bank's 2006 Conference on Development Economics in Tokyo, Professor Michael Grubb of the UK Carbon Trust complained that scientists and economists were talking past each other about the challenges of climate change:

> "To date, this debate on impacts between economists quantifying specific, potentially measurable and monetizable impacts, and scientists focused on risk indices and scenarios, has been largely a dialogue of the deaf."(1)

1. Grubb, M (2006), "Climate change impacts, energy, and development", Paper presented

The same may be said about the engagement in climate policy discussions of the community of built environment practitioners, particularly the engineers who conceive, design, build and operate the physical infrastructure that sustains our urban societies.

The approach to the provision and management of that infrastructure will, in substantial measure, determine the future vulnerability or, to use the inverse, the resilience of urban communities to climate-related disasters. Despite this, relatively little work has been done on the potential impacts of climate change on urban settlements in high-income nations, and even less in low- and middle-income nations that are most vulnerable. The principal focus has remained on the contribution of urban activities to climate change, mitigating their effects rather than adapting to them.[2]

There is an important debate about the relative importance for different societies of mitigation, which addresses the drivers of climate change, versus adaptation, which considers the measures necessary to accommodate such changes.[3] The "development rather than mitigation" view has been most succinctly expressed by environmental "dissident" Bjorn Lomborg who recommended that:

> "…we should not spend vast amounts of money to cut a tiny slice of the global temperature increase when this constitutes a poor use of resources and when we could probably use these funds far more effectively in the developing world."[4]

A further consideration, particularly in poorer countries, is whether it is necessary to distinguish between adaptation-specific activities and "normal" development.

A strong case can be made for the allocation of additional development funds to address the impacts of climate change in poorer countries on the basis of the "polluter pays" principle. However, if resources are to be usefully directed to adaptation, there will have to be clarity about the strategies proposed to do this, as well as some evidence of their efficacy. It is thus important to consider how adaptation efforts can fit within the mainstream of development strategies. In this, the water sector may provide some useful indicators and guidance in the broader debate.

It is urgent to move beyond the mitigation and adaptation debate if only, as Professor Grubb said, because the infrastructure we build today locks us into patterns of behaviour for many years to come. He further noted that: "*'Leapfrogging' in infrastructure, by trying to make choices at the leading edge for the long term, is … a huge opportunity in the course of development.*"[5]

Grubb was addressing primarily energy and development issues, which are where the main mitigation challenges lie. Yet the point is even more valid in the water environment, which arguably will be most affected by climate change in such key parameters as river flow.[6] Further, unlike energy infrastructure, the useful life of large water infrastructure is often measured in hundreds of years, and investments that are made today will still be operating under the new climates of the twenty-second century.

While the role of water management in mitigating flood and public health disasters is well recognized,[7] its effective execution may also have a role in preventing less obvious slow onset disasters that are more insidious but arguably as damaging, since they may lead to the collapse of the social, political and financial viability of urban settlements.

at the Annual World Bank Conference on Development Economics, 30 May, Tokyo, page 9.

2. Gagnon-Lebrun, F and S Agrawala (2006), "Progress on adaptation to climate change in developed countries: an analysis of broad trends", ENV/EPOC/GSP(2006)1/FINAL, OECD, Paris.

3. Tol, R S J (2005), "Adaptation and mitigation: trade-offs in substance and methods", *Environmental Science & Policy* Vol 8, pages 572–578.

4. Lomborg, B (2001), *The Skeptical Environmentalist: Measuring the Real State of the World*, Cambridge University Press, Cambridge, 540 pages.

5. See reference 1, page 26.

6. IPCC (2001), "Summary of climate changes and likely impacts on water resources", Report of Working Group II, Intergovernmental Panel on Climate Change.

7. United Nations (2002), "Plan of implementation of the World Summit on Sustainable Development", accessible at http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf.

This paper considers the physical and financial implications for urban areas of the potential impacts of climate variability and change on water resources. The issues are illustrated in the context of sub-Saharan Africa, which is predicted to be one of the regions most affected and is certainly among the most vulnerable. Some potential impacts on urban communities are outlined, and areas identified in which different practice could achieve better outcomes for city dwellers. Information and instruments required to translate the desirable interventions into practical programmes of adaptation are highlighted which, if given the same priority as climate change mitigation, could help to make urban settlements more resilient to many types of disaster. Finally, a brief review is made of the financial and institutional approaches that will have to be addressed to promote effective adaptive action.

II. INSTRUMENTS TO MANAGE VARIABILITY, REDUCE VULNERABILITY AND BUILD RESILIENCE

Building resilience to manage the impacts of variable climates on human activity is the day-to-day business of water managers, whether in planning for weather extremes or optimizing long-term resource utilization. This has been done throughout the history of human settlements. Much of the simplest traditional water infrastructure, the household rainwater cistern, the "tank" in the Indian town, enables households and communities to manage the variability of the water resources on which they depend which, in turn, reflects their local climate. The same is true for the simple river training, floodwalls and flood diversion canals that protect many of the world's towns and cities.

Over time, quantitative climate information and assumptions have been embedded more formally into the design of this essential infrastructure as well as that of the water distribution and waste collection networks, roads and stormwater drains, and human settlements more generally.

One way to manage the impacts of climate variability on water resources is to capture and control river flows. Dams are built to retain and store flows that are in excess of user requirements and to release them during periods when low flows are not sufficient to meet user needs, a practice that can also serve to maintain aquatic ecosystems. Alternatively, during floods, peak flows can be stored for later release, avoiding flood damage by reducing maximum flows. Both functions are important to sustain urban settlements and to avert disasters caused by floods and droughts.

A further important function of dams is to store water as a form of potential energy to generate electricity, without which healthy urban life is difficult to sustain as settlements increase in size. Nineteen per cent of the world's electricity is currently generated from hydropower and there is substantial potential to expand this, particularly in low- and middle-income countries.[8] A specific benefit of hydropower is that it does not usually generate significant quantities of greenhouse gases and thus allows economic and social development to occur without aggravating global warming.

Other important waterworks include canals, tunnels and pipelines, which not only supply human demands directly but, less obviously, create linked systems that, by virtue of their multiple sources, suffer less

8. UNESCO (2003), *Water for People, Water for Life; the First UN World Water Development Report*, United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books, Paris.

variability and therefore offer enhanced supply security. Equally, wastewater disposal and stormwater drainage systems contribute to the ability of communities to maintain their activities and protect public health during extreme weather events.

The design of all these structures reflects formal, quantitative assumptions about climate, since it takes into account likely variations in rainfall and stream flow as well as likely storm intensities and maximum flood sizes.

The water managers' armoury for addressing variability is not restricted to infrastructural means. As important are the institutional mechanisms that, again more or less formally, help to deal with climate variability and achieve such goals as supplying water for people, industries and farms, and protecting communities from flooding while sustaining ecosystems.

An obvious example is rules on water allocation that prioritize different uses of water at different times. In many countries, water law and management practice applies categories such as "winter water" and "surplus flow" to determine who can use how much water and when. From this perspective, organized drought restrictions should not be seen as supply failures but, rather, as institutional mechanisms to manage variability by prioritizing different water uses during times of supply stress.

Beyond direct water management, institutional instruments such as land use planning can substantially reduce the vulnerability of communities to water-based natural disasters if they are supported by reliable flood data that can be provided by water managers. There is often a choice from a suite of hard and soft instruments that can be applied to enhance resilience. In the case of floods, resilience can be achieved by building infrastructure such as floodwalls; alternatively, communities can be designed to be resilient by planning approaches that do not allow settlements to be located in vulnerable areas; often, a mix is most appropriate.

III. THE DEVELOPMENT CONTEXT AND CONSTRAINTS BEFORE CLIMATE CHANGE

It might be expected that the threat of climate change would encourage greater attention to building the capacity to manage the impacts of general climate variability on water resources. This is not (yet) to say that such specific action is required in water resources management concerning climate change, although the case is growing stronger. A risk-based approach would suggest that the evident uncertainty about the climatic future should mean more explicit attention to mechanisms that could help manage it; from there, it is a small step to recognizing that the bounds of variability may be changing.

It is not clear whether that is happening yet, precisely because water resources management is already so focused on dealing with climatic and weather variability and there is, as yet, only limited scientific evidence for increased variability beyond historic norms. It has been noted that most human societies are inherently adaptive; however, it is anticipated that climate change will test these coping capacities, which will need to be strengthened.[9]

9. Adger, W N, S Huq, K Brown, D Conway and M Hulme (2003), "Adaptation to climate change in the developing world", *Progress in Development Studies* Vol 3, No 3, pages 179–195.

Meanwhile, many poorer countries are not even able to manage their current variability, not because the necessary strategies are unclear but because the means to implement them are lacking. They may reasonably ask why they should address tomorrow's climate change if they cannot afford to manage today's drought.

This is evident in the challenge of maintaining reliable urban water supplies. In low- and middle-income countries generally, and in sub-Saharan Africa in particular, both industrial and domestic consumption are growing and more water will be needed. The nature of urban living and modern industry requires those sources to be reliable in the short term and assured over longer time periods.

At first sight, sub-Saharan Africa's challenge is not so great. Of the 295 million urban residents in Africa, 254 million are reported to already have "improved" water supplies,[10] (although, currently, these services are often not functioning effectively).[11] Assuming that the volumes consumed remain the same, only a manageable 15 per cent increase in the amount supplied would be required to reach 100 per cent. However, urban growth of at least 50 per cent, or 150 million people, is predicted between 2000 and 2015.[12] If this occurs, a 60 per cent increase in water volumes would be required if all urban residents were to be adequately served.

The challenge – and the opportunity – is to meet these needs in a manner that "leapfrogs" the current approaches and puts the countries and cities concerned into a position that allows them not just to meet these new needs but to do so in a manner that leaves them more resilient to the potential impacts of climate change. This would involve such "soft measures" as conservation programmes that would moderate the growth in demand. Another effective approach would be to design cities with denser housing (rather than larger gardens), which has been shown to reduce water use.[13] In poorer countries, however, this might be at the expense of domestic food security.

Whatever strategy is chosen, substantial investments will be required. An important question is thus what impacts climate change could have on the nature and costs of the investments required to meet urban water needs in Africa and other poor regions.

IV. THE CHALLENGES OF CLIMATE CHANGE FOR WATER RESOURCES MANAGEMENT

To address this question in the water sector, it is necessary first to consider the potential impacts of climate change on water resources and their management. The general picture of global warming is reasonably clear, and agreement is growing about its regional dynamics and scale. However, moving from temperature predictions to reliable predictions of seasonal rainfall and its distribution in time is already a big leap. The current rainfall predictions are indicative rather than definitive and are still relatively general, which limits their utility for indicating the type of strategic challenges that may arise. Similar caveats apply to the other key dimension of climate variability that has an impact on water resources and their management, namely the predictions that there will be significant changes in weather extremes, with more powerful, intense, storms and longer, more intense droughts.[14] This would be consistent with the

10. See reference 8.

11. Thompson, J, I T Porras, E Wood, J K Tumwine, M R Mujwahuzi, M Katui-Katua and N Johnstone (2000), "Waiting at the tap: changes in urban water use in East Africa over three decades", *Environment & Urbanization* Vol 12, No 2, October, pages 37–52.

12. United Nations (2006), *World Urbanization Prospects: The 2005 Revision*, United Nations Population Division, Department of Economic and Social Affairs, CD-ROM Edition – data in digital form (POP/DB/WUP/Rev.2005), United Nations, New York.

13. Jansen, A and C E Schulz (2006), "Water demand and the urban poor: a study of the factors influencing water consumption among households in Cape Town, South Africa", Working Paper No 02/06 in Economics and Management Series, January, Department of Economics and Management, Norwegian College of Fishery Science University of Tromsø, Norway.

14. IPCC (2001), "Climate change 2001; impacts, adaptation and vulnerability", Report of Working Group II of the Intergovernmental Panel on Climate Change, Hydrology and Water Resources Section.

underlying analyses of energy flows that underpin predictions of global warming, and of great importance for water managers who necessarily focus on extreme events.

The more difficult questions relate to the impacts of changing temperatures and rainfall on water availability. To fully understand the impacts of climate change on urban communities, it is necessary to be able to predict average rainfall and stream flows (to determine water availability and storage requirements) as well as extreme flows and storms (to design infrastructure to withstand them); also to predict potential changes in groundwater yields.

The effects of climate change on available water (as opposed to rainfall) are more difficult to predict because a number of effects combine. Crudely put: if temperatures increase, there will be more evaporation from the soil and transpiration from plants, and less water will flow into rivers or seep into the underground aquifers; but if rainfall is more intense, a larger proportion of water will flow off the ground as floods or infiltrate through the soil into the deeper groundwater.

Changes in carbon dioxide concentrations, temperature and rainfall will have an impact on plant cover and land use which will, in turn, substantially affect the behaviour of water when it falls as rain. And there are direct anthropogenic impacts to be considered – changes in land use, for example cropping systems, will also affect the availability of water and add a further layer of complexity to the uncertainty about the "natural" processes.

It is thus clear that the prediction of stream flows and groundwater regimes under climate change scenarios is an ambitious undertaking; although efforts have been made for some regions, they still provide a relatively wide range of possible outcomes.(15)

The important conclusions for the purposes of this paper are that:

- changes in temperature and rainfall will usually be amplified in the response of water resources systems, with relatively small (10–20 per cent) changes in rainfall leading to large (up to 75 per cent) changes in perennial stream flow; and
- uncertainty grows as extrapolations are made from climate models related to temperature predictions, to rainfall predictions and finally to predictions of the stream flow consequences.

Paradoxically, one consequence of the wide uncertainty is that water managers still use historic climate data to design water infrastructure. Thus, in order to determine the likely yield of a dam, the usual approach is either:

- to use an historic record of the flows in relevant streams and rivers to determine how much water can reliably be made available; or
- to use rainfall and runoff data from a similar area and "synthesize" an artificial "record" of flows.

In both cases, parameters derived from historic information will be used to generate a series of predictions of possible stream flow sequences against which the performance of the structure will be evaluated. The details of these approaches are not important for the purposes of this paper save to say that both are dependent on local or related historic records of stream flow and rainfall and, as important, on the ability to use the data and translate them into useful information.

15. See, for instance, Hewitson, B, F Engelbrecht, M Tadross and C Jack (2005), "General conclusions on development of plausible climate change scenarios for Southern Africa", in R E Schulze (editor), *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*, Water Research Commission Report 1430/1/05, WRC, Pretoria, Republic of South Africa, Chapter 5, pages 75–79; also de Wit, M and J Stankiewicz (2006), "Changes in surface water supply across Africa with predicted climate change", *Science Express*, on-line article page 1/ 10.1126/science.1119929, accessible at www.sciencemag.org/sciencepress/recent.dtl.

A practical example of the challenges posed by climate change is the decision that will have to be taken in South Africa within the next decade concerning the source of the next major increment in water supply to the metropolitan area of Johannesburg and its surrounding industrial heartland. There are two main options:

- to expand the existing Lesotho Highlands Water Project, taking more water from the Orange River system that rises in the mountains of Lesotho and flows to the Atlantic Ocean on the border with Namibia and putting it into the Vaal system; or
- to capture water from the other side of the divide, from the Thukela and other shorter, smaller rivers that flow to the Indian Ocean on the East Coast and transfer it into the Vaal basin.

Whichever option is chosen, this will be an expensive project, costing over a billion dollars and taking up to a decade to plan and build, so decisions cannot be taken lightly. The comparative costs of the alternatives are not dissimilar.

Factors that will affect the decision include: differences in operating costs, since one solution will require less pumping than the other; and political considerations, since the existing treaty between Lesotho and South Africa provides for further phasing of existing transfers, and a further phase would bring a substantial cash injection to Lesotho. Capital costs will, however, always be an important determinant of the lifetime cost of water delivery, so the comparative costs of the alternatives are an important issue. But apparent differences in the unit cost of water calculated for each scheme may be meaningless if the hydrological forecasts on which they are based are not reliable or comparable.

Climate science offers only limited help in making this decision. Thus it is currently suggested that for South Africa, in terms of rainfall, the west and southwestern parts will become drier, and the east of the country will stay the same and may even become wetter. (16)

16. See reference 15, Hewitson et al. (2005).

In this case, climate predictions would suggest that it might be less risky to opt for an eastern river source, which is predicted to be less affected by climate change (less risky) and would have the advantage of maintaining a balance between different sources – a more resilient system. But it is not clear how much weight should be given to these criteria. Nor is it known how firm the numbers will be when the decisions have to be made and firm information – about, say, project costs – traded off against what is at present far less precise climate information.

This example illustrates why many practitioners argue that it is not yet possible for water managers, in low-income countries in particular, to take climate change into account in their designs. Yet the logic remains that water investments should be designed to perform under future climate regimes. The present challenge is thus to improve the descriptions of those possible regimes by reducing the uncertainties that multiply at each step of the hydrological cycle, from temperature predictions to estimates of rainfall, evaporation, infiltration and runoff, to obtain reasonably reliable predictions of stream flow and groundwater availability. If these flows can be predicted better, they can be managed better.

The underlying concern remains that if rainfall changes, if the increased variability and event intensity that is predicted actually occurs, this will impose substantial costs on poor countries. The next step is thus to gain some indication of the magnitude of those costs and then to consider how they might be addressed.

V. WATER RESOURCES COSTS: THE ADDED BURDEN OF ADAPTATION

For policy purposes, it is important to distinguish between the costs of managing "normal" climatic variability and those of managing the new impacts of climate change. If climate change is driven by the activities of certain communities or countries, it may be appropriate to apply the "polluter pays" principle, which would have significant implications for financing the costs that may be incurred. However, the boundary between "normal" and "new" variability is not obvious. It is thus difficult to determine what proportion of a dam helps to manage "normal" variability and what proportion the "new" variability "created" by climate change.

Preliminary estimates of some of the additional costs that may be imposed on cities in sub-Saharan Africa have been made by the author,(17) in an attempt to determine their order of magnitude as well as identify some of the underlying issues. Changes in rainfall patterns and stream flow will have a direct impact on cities, some of which are very obvious:

- water supply is costly and, if availability of water is reduced by climate change, larger conurbations will have to change their consumption patterns or bring their water from further afield;
- standards for wastewater treatment typically depend on the extent to which effluents can be diluted when they are discharged; so if stream flows are reduced, treatment must be intensified to maintain the same environmental standards. Municipal wastewater collection and treatment is already the most costly element of infrastructure required to meet Millennium Development Goals (MDGs) for health, water and environmental protection(18) and, since treatment costs increase exponentially with the degree of purification required, climate change could add substantially to the burden of meeting these MDGs;
- any increase in the intensity of rainfall, and therefore flooding, as a consequence of climate change will increase the cost of roads and stormwater drainage as well as of flood protection works; and
- many cities in sub-Saharan Africa are dependent on hydropower for their electricity, and power failures can lead to more general "urban failure".

There are also less direct effects:

- flood risk affects the area of land available for settlement as well as the cost of protecting vulnerable land from flooding (the challenge of sea-level rise, which is relevant for many coastal cities, is not considered here); and
- bringing water from further afield not only increases the cost of water but also expands the area affected by competition with cities for water. This will have economic impacts on the cities themselves, whether through higher prices for rural products or the aggravation of rural unemployment, leading to urban migration.

Accurate costings of these impacts will obviously depend on the details. However, to obtain an order of magnitude estimate of the potential cost implications of climate change for African cities, the following first-order assumptions have been made:

- the reliable yield from dams will reduce at the same rate as stream flow: a 30 per cent reduction in average stream flow will result

17. Muller, M (2006), "Living with climate: can the water sector lead in building resilient societies?", presented at the Conference on Living with Climate Variability and Change: Understanding the Uncertainties and Managing the Risks, 17–21 July, Espoo, Finland, accessible at http://www.livingwithclimate.fi/linked/en/Muller_text.pdf.

18. Camdessus, M (chair) (2003), "Financing water for all", Report of World Panel on Financing Water Infrastructure, Global Water Partnership/World Water Council Third World Water Forum, 16–23 March, Kyoto.

in 30 per cent less yield and the unit cost of water will go up by more than 40 per cent;

- where waste is disposed into a stream, if stream flow is reduced by 30 per cent, the pollutant load must be reduced by 30 per cent. Since to achieve lower pollution levels, treatment costs increase rapidly, it is reasonable to assume that the overall cost of wastewater treatment could double; and
- power generation reduces linearly with stream flow (the true situation is somewhat more complex and depends on the way in which schemes are operated); a 30 per cent reduction in stream flow will result in a 30 per cent reduction in electricity production.

19. See reference 17.

Applying these assumptions, and using unit costs derived from actual project experience,[19] the costs of adapting existing urban water infrastructure in Africa have been estimated at between US$ 1,050 million and US$ 2,650 million annually:

Urban water storage	US$ 500–1,500 million (capital cost)
	US$ 50–150 million (annual equivalent)
Wastewater treatment	US$ 100–200 million annually
Electricity generation	US$ 900–2,300 million annually

(this does not include the cost of rehabilitating deficient infrastructure)

The costs of new development are also likely to rise by between US$ 990 million and US$ 2,550 million annually. In general, the marginal unit cost of water resources development for water supply to urban areas increases with each new increment of supply. It is therefore conservative to assume that the costs of adapting to climate change for new developments will be similar to those for existing systems:

Urban water storage	US$ 150–500 million (capital cost)
(new water supplies for 150M)	US$ 15–50 million (annual equivalent)
Wastewater treatment (assuming an additional 100M served)	US$ 75–200 million annually
Electricity generation (assuming installed capacity doubles)	US$ 900–2,300 million annually

There are many other costs that will be imposed on urban areas through the water cycle. The economic impacts of rural water shortages on urban areas are particularly difficult to quantify. However, urban migration is a management challenge for almost all African cities, and any declines in rural production will certainly have second-order impacts on city economies.

There will also be additional costs incurred in the construction of roads and storm drainage, from the loss of use of land that is threatened by floods, and for additional flood protection for existing settlements. These and other indirect effects are site-specific and less easy to cost on a regional level.

The issue of flooding highlights the fact that climate change may not always be negative, as the availability of land for urban settlement may be positively affected by a reduction in rainfall. However, if the frequency and intensity of extreme storms rises, flood lines may not change significantly in a drier future, which would counter any possible expansion of habitable area. All these effects call for elucidation and quantification to enable communities to understand what will be needed to deal not just with current variability but also with changes in its nature.

While this discussion has focused on the costs of actions to address the potential water-related impacts of climate change, a final critical point needs to be made. If the actions identified to make urban settlements more resilient are not taken, flood disasters, water and electricity supply interruptions, with the resulting economic public health and economic implications, will occur. The costs of such disasters will almost certainly be greater than the costs of prevention through appropriate adaptation measures. At the extreme, if disasters place unsustainable financial burdens on urban societies, this could lead to the collapse of public services, and climate change will have created "failed cities".

VI. SOME PRACTICAL CHALLENGES AND RESPONSES

a. Financial challenges

The additional costs outlined above (US$ 2–5 billion annually) could feasibly be met from national sources given current levels of expenditure, supplemented by aid funding which, in the case of sub-Saharan Africa reached US$ 23,276 million in 2004.[20] They do, however, demonstrate that climate change could add substantially to the overall cost of urban management and of doing business in urban areas (which is already high and, arguably, underfunded). This will have an impact on the ability of urban centres in low-income nations to compete in an increasingly globalized economy and will undermine their ability to sustain themselves. In this more generic manner, the impacts of climate change through water threatens to leave them more vulnerable to disaster. Specific responses are therefore needed to the challenges that are emerging.

This concern is shared in a working paper of the British government's Stern Review:

> "… the adverse impacts of climate change will be felt most acutely and soonest by poor people in developing countries, in particular in Africa, because of their geographical and climatic conditions, their high dependence on agriculture and the natural environment, the deficiencies in their infrastructure, and their limited capacity and lack of financial and technical resources to adapt."

An equitable international response to climate change must include not just action on mitigation, therefore, but also finding ways of working with the most vulnerable countries and regions to ensure their growth and poverty reduction goals are not compromised."[21]

Another recent review of the challenges of funding the costs of adapting to climate change asked whether these should be funded through the 1992 UNFCCC (Framework Convention on Climate Change) or through other channels, and concluded that a twin-track approach would be appropriate.[22]

Certain institutional interests would seek to ring-fence funds for climatic adaptation purposes. Given the difficulty in distinguishing between adaptation and normal development, this is likely to lead to sub-optimal investments. The present approach of the UNFCCC, which tends to separate climate adaptation from the "normal" development

20. OECD (2006), *DAC Development Cooperation Report 2005*, Development Assistance Committee, OECD, Paris.

21. Stern, N (2006), *Review of the Economics of Climate Change. What is the Economics of Climate Change?* Discussion Paper, Her Majesty's Treasury, UK Government, 31 January.

22. Bouwer, Laurens M, C Jeroen and J Aerts (2006), "Financing climate change adaptation", *Disasters* Vol 30, No 1, pages 49–63.

and management activities, has been questioned. The result, say Bouwer and Aerts, is that "*…most of the proposed funding … is limited to capacity building (such as joint research and knowledge exchange) and does not include the provision of funds for the implementation of adaptation*."[23]

23. See reference 22, page 56.

On efficiency grounds, the objective should be for adaptation efforts to be integrated into the mainstream of development rather than kept in a climate and sustainability "ghetto". For low-income countries that are aid dependent, particularly in sub-Saharan Africa, the objective should be to place additional funding in appropriate national budgets and support the planning and budgeting processes to ensure that new investments are "climate-proofed". This would be consistent with the 2005 Paris Declaration on Aid Effectiveness,[24] although it may frustrate those who wish to see quick and dedicated climate-related action.

24. Paris High Level Forum (2005), Paris Declaration on Aid Effectiveness, Ownership, Harmonization, Alignment, Results and Mutual Accountability, OECD/Development Assistance Committee, Paris.

The Paris Declaration offers a more elegant and integrated approach but, to take advantage of the opportunities it offers, the countries concerned will need to put credible planning and budgeting processes in place. It would also be necessary to build into existing monitoring and reporting mechanisms ways to track expenditure related to adaptation activities. The objective should be to keep governments (on both sides) honest about the processes of resource mobilization and allocation, as well as to focus continued attention on the need to integrate climate adaptation into normal development activities.

b. Institutional challenges

Considerations of finance for adaptation lead logically to the institutional issues. One relevant institutional response is the emergence of the philosophy and methodology of Integrated Water Resources Management (IWRM). Although some advocates see it as a "soft" alternative to infrastructure development, relying solely on instruments such as demand management, IWRM promotes an holistic approach to water management and recognizes that there are multiple pathways to building resilience. The methodology seeks to identify and then to achieve tradeoffs between different water management objectives, including environmental sustainability, economic efficiency and social equity, all of which have implications for disaster mitigation. It encourages the structured engagement of communities and sectors affected by water into its management, to ensure both that optimal (direct and indirect) mechanisms are identified, considered and applied, and that an understanding of water constraints and challenges is diffused into the society.[25]

25. Global Water Partnership (2000), Technical Advisory Committee, Integrated Water Resources Management Background Paper No 4, GWP, Stockholm.

The potential contribution of an IWRM approach to the achievement of sustainable development was emphasized by world leaders at the 2002 World Summit on Sustainable Development, where they agreed that all countries should establish water management plans by 2005 (a target that has proved to be aspirational and motivational rather than practical, but no less important for that).[26] The challenge is now to undertake the institutional and technical work that will make it possible to translate the policy aims of IWRM into practice, in disaster management as well as in other dimensions. The mainstreaming of adaptation or "climate proofing" into national development plans is a key institutional action for which IWRM offers a potentially useful channel.

26. See reference 7; also Global Water Partnership (2006), "Setting the stage for change", second informal survey by the GWP network giving the status of the 2005 WSSD target on national integrated water resources management and water efficiency plans, GWP, Stockholm, February.

c. Technical challenges

There are serious practical challenges facing climate scientists and water managers who seek to build the resilience of urban settlements to climate change. The quality of the climate and hydrological information needed to design new water management infrastructure is grossly deficient. In poorer developing countries, this has not been particularly obvious over the past decade because of the decline in investment in water infrastructure during the period. This was a result of financial constraints as well as donors' attempts to achieve greater private sector investment, and their concerns about the social and environmental impacts of large water projects.(27) It is now recognized that additional investments are required and that public channels are appropriate, particularly for large long-term investments which, historically, in order to be undertaken have required public finance by virtue of the long-term nature of their returns.(28)

A natural consequence of the drought in water investments over the past few decades is that less priority has been attached to collecting and processing the hydrological data that are used to support them. This has contributed to a marked decline in hydrological networks over recent decades.(29) This trend has been exacerbated by progress in the use of remote systems in other dimensions of observation, which has reduced dependence on terrestrial networks; detailed hydrological observation has yet to benefit from such remote platforms.(30)

Many poorer countries thus have limited information to support the planning, development and management of water. This situation cannot be reversed overnight since, to be most useful, hydrology requires long, relatively complete records and there is a danger that, when the investment tide turns, it will not be possible to use the new funding flows optimally. There is a growing awareness that existing design standards are perhaps no longer applicable. As one practitioner commented:

> "Marked changes in design floods are possible … with potentially serious repercussions in design hydrology. In the absence of more comprehensive understanding, it is not possible to make reliable predictions at present, so practitioners are faced with the risk of either over-designing their infrastructure or incurring potentially unacceptable levels of risk."(31)

> "Design hydrology will, therefore, in all likelihood, have to be re-evaluated in the light of anticipated climate change and the enhanced climatic variability associated with this change."(32)

The rehabilitation of hydrological monitoring infrastructure, and the recovery and use of existing as well as new data to provide hydrological design parameters that reflect the risk of climate change-induced variability are among the areas where "leapfrogging" into the future is possible. But, while the development of methods for remote monitoring of stream flow is on the global climate agenda, there is little urgency, perhaps because the promised water investments have yet to create the demand. Similarly, many countries have yet to begin to review their design standards from a climate change perspective. Delays in this area will leave urban communities and poor countries more vulnerable to natural disasters than they need to be.

27. Muller, M (2007), "Parish pump politics – the politics of water supply in South Africa", *Progress in Development Studies* Vol 7, No 1 (forthcoming).

28. See World Bank (2004), *Water Resources Sector Strategy*, World Bank, Washington DC; also see reference 2.

29. WMO (2003), "Networks, availability and access to hydrological data", Memorandum by Dr W Grabs, Chief, Water Resources Division, WMO, (retrieved from Global Runoff Data Centre, www.grdc.bafg.de. September 2006); also Washington R, M Harrison and D Conway (2004), *African Climate Report*, commissioned by the UK Government to review African climate science, policy and options for action, DFID, London.

30. See reference 17.

31. Schulze, R E (2005), "Case study 2: potential impacts of shifts in hydroclimatic zone on design hydrology from small catchments in Southern Africa", in Schulze (2005), see reference 15, Chapter 13, pages 241–247.

32. Schulze, R E (2005), "Adapting to climate change in the water resources sector in South Africa", in Schulze (2005), see reference 15, Chapter 27, pages 423–449.

VII. CONCLUSION – WATER RESOURCES MANAGEMENT COULD BE A LEAD SECTOR IN ADAPTATION TO BUILD URBAN RESILIENCE TO CLIMATE CHANGE

Over the past two decades, energy has rightly taken centre stage in the climate change debates, with a focus on mitigation. The stakes are high since mitigation measures affect the very structure of the world's energy and industrial economies. While mitigation was correctly the initial focus, because prevention is always better than cure, attention must necessarily turn to adaptation, as yesterday's predictions become today's realities. This is evident in urban areas, where a failure to address the impacts of climate change on water resources will leave their inhabitants vulnerable to a range of immediate acute and slow-onset disasters.

These include:

- flood damage to urban settlements;
- water and electricity supply failures impacting on public health as well as on the economic performance and sustainability of urban communities; and
- financial costs that will render water and related services unaffordable, and potentially causing their collapse, with the same results.

While the costs are high, as illustrated by the costings presented earlier, they are not nearly as high as those required to meet the challenges of mitigation, estimated by the IPCC to be between US$ 60 billion and US$ 240 billion.[33] Adaptation measures will, in many cases, be integral to the process of achieving the social goals established in the Millennium Declaration.[34] And beyond the MDGs, building resilience into water management systems will also be critical in meeting the needs of economic water users on whom urban economies depend.

For these reasons, the water sector may provide practical opportunities, at a realistic scale, to begin to make progress towards the goals of adaptation while the debates about the restructuring of the world's energy and industrial technology platforms continue. Water could become a lead sector in the process of developing appropriate models for financing the implementation of adaptation.

The sooner a start is made, the easier it will be to accommodate adaptation into "normal" development. Conventional public finance approaches, if applied globally, would invest in adaptation now to avoid later crisis spending. In the context of the reform of overseas development assistance, the most effective approach would be to link additional budget support transfers to planning and budgeting processes that are enhanced to identify adaptation elements of existing spending items. In a world where rules were just and fair, a substantial proportion of these incremental costs would be met by those whose actions have imposed them, in terms of the "polluter pays" principle.

Effective action for adaptation has hardly begun, but there are many opportunities. Climate change is a slow-onset disaster that offers communities and nations time to adapt. The water cycle offers its own natural learning opportunities; it can be a patient teacher for those who are willing to learn.

33. IPCC (2001), "Summary for policymakers: the economic and social dimensions of climate change", Report of Working Group III, Intergovernmental Panel on Climate Change.

34. UN (2000), *United Nations, Millennium Declaration*, A Res 55/2, September 2000, New York.

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