Water for Growth and Development*

A Theme Document of the 4th World Water Forum

*This document was prepared by David Grey, Senior Water Advisor, and Claudia Sadoff, Lead Economist, The World Bank. The findings, interpretations, and conclusions expressed herein are those of the author(s) and do not necessarily reflect the views of the IBRD/The World Bank and its affiliated organizations, or those of the Executive Directors of The World Bank or the governments they represent..

Water for Growth and Development

"*Water is a blessing for human kind. It is the life blood of farming. Nations, cities and civilizations have grown near rivers. Our scriptures have praised the life giving quality of water. At the same time, having an excess of water or its complete absence can be a curse too. Last year, many parts of our country were affected by drought. Farmers were in acute distress. This year, we are having a deluge of water, leading to flash floods and consequent destruction and loss of valuable property in many States of the Union. Once again, farmers in these parts are in distress. In a way, these two phenomena demonstrate the vulnerability of our people to the vagaries of nature. They also demonstrate the importance that irrigation can play in mitigating the risk arising out of fluctuating rainfall – both when it is in shortage and when it is in excess. Irrigation can ensure that people's suffering from water related disasters is minimized and that they enjoy the benefit of nature's bounty."*

Speech by Dr. Manmohan Singh, Prime Minister of India, at the Inauguration of the National Conference of Irrigation and Water Resources Ministers, November 30, 2005.

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Executive Summary

At the request of the Secretariat of the Fourth World Water Forum, this paper has been prepared to serve as a "reference point for discussion" on the theme of Water for Growth and Development. It seeks to raise a very basic question – *how can water resources be managed and developed to promote growth and alleviate poverty in a responsible manner?* The dynamics of water, growth and poverty are extremely complex, and highly dependent upon specific physical, cultural, political and economic circumstances. The immediate goal of this paper is therefore to provoke discussion and strengthen understanding of the importance of water resources management and development in enabling responsible economic growth and poverty alleviation – fully mindful of the fact that this is just one of many aspects that must be weighed and understood in managing water resources. The paper's broader objective is to contribute to a constructive, comprehensive dialogue that will help inform the difficult trade-offs inherent in water management, and assist decision makers in finding the most acceptable balance among human aspirations for growth and poverty alleviation, social and cultural integrity, and environmental sustainability.

Water as a Source of Destruction and Poverty – or Production and Growth?
Water has always played a central role in human societies. Water is a key driver of sustainable growth and poverty alleviation as an input to almost all *production*, in agriculture, industry, energy, transport, by healthy people in healthy ecosytems. It can be a force for *destruction*, catastrophically through drought, flood, landslides and epidemic, as well as progressively through erosion, inundation, desertification, contamination and disease. Water is quite literally a source of life and prosperity and a cause of death and devastation. This destructive aspect of water, as a consequence of its extraordinary power, mobility, indispensability and unpredictability, is arguably unique.

Achieving basic water security, harnessing the productive potential of water and limiting its destructive impacts, has been a constant struggle since the origins of human society. Throughout history, water has also been a source of dispute and even conflict between uses and between users at both local and larger scales. As water becomes ever more scarce relative to demand, there are emerging fears of transboundary waters becoming a source of conflict, constraining growth; conversely, there is also emerging experience of cooperation on transboundary waters, supporting regional integration as a driver of growth.

As then so today, water resources development and management remain at the heart of the struggle for growth, sustainable development and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in water infrastructure, institutions and management capacity. It remains the case in many developing countries today, where investments in water development and management remain an urgent priority. In some developing

countries – often the poorest – the challenge of managing their water legacy is almost without precedent.

Learning from Experience

In the late 19th and early 20th Centuries, all industrialized countries invested heavily in hydraulic infrastructure and institutions to facilitate their remarkable economic growth. However, many of the inevitable tradeoffs in water resources infrastructure development were poorly structured and/or projects were poorly implemented, to the detriment of project-affected communities and local natural environments. As a consequence, in recent years a great deal of controversy has grown around water infrastructure development, and particularly large-scale water infrastructure. This has led to a fairly general perception that water resources infrastructure development is *intrinsically* bad for the poor, bad for project-affected people and bad for the environment. This perception has become a barrier to financing water development, affecting countries with limited infrastructure (generally poorer), more than countries with mature infrastructure platforms (generally richer).

But there is no fundamental constraint to designing water development investments to ensure that local communities and the environment share real and early benefits while still allowing the economy and society at-large to benefit from the growth made possible by these investments. Moreover the poor are those who are generally most vulnerable to the destructive impacts of water, and those with the least opportunity to exploit the production opportunities that water can provide – suggesting that absolute inaction may in fact be intrinsically anti-poor. There are many lessons from both good and bad experiences that can provide insights for all countries to strengthen institutions and management capacity, ensure better design of new (or operation of existing) water resource infrastructure, and strive for equity in the sharing of benefits. The knowledge gained from experience, often at great environmental and social cost, must be used to help guide new policies, reforms and investments to achieve growth in a more equitable and sustainable – and responsible – manner.

Responsible Growth

There is a re-emerging consensus that water resources development and management are essential to generate wealth, mitigate risk, and alleviate poverty;[1] that poverty demands that many developing countries will need to make large investments in water infrastructure at all levels; and that this development must be undertaken building on the lessons of experience, with much greater attention to institutional development, to the environment and to more equitable sharing of benefits and costs. The challenge of "Responsible Growth" is to grow while at the same time embracing both environmental sustainability and social development.[2] A responsible path is particularly important in water development

[1] (SIWI 2005).
[2] Hamilton and Johnson (2004).

because, given the longevity of water infrastructure, many of these decisions will have long-term consequences. Furthermore many decisions – both decisions to act and not to act – may have irreversible consequences.

Stories of Water and Growth

In all ***industrial countries***, the flows of almost all major rivers are regulated and managed, storing water for multiple uses, reducing peak flows, increasing low flows and protecting water quality, thus reducing the risk of water-related shocks and damage, increasing the reliability of water services for production, and reducing other negative impacts, such as disease. In many, but not all, industrial countries, climate seasonality, variability and extremes are limited in extent, implying that societies that did not have to combat an adverse climate regime had one less development barrier to overcome, facilitating earlier, easier growth.[3] Early and large investments have been made in bulk water infrastructure and in the human capacity required to operate and maintain these investments. In most cases, the infrastructure platform is mature and much greater emphasis is placed on water management and infrastructure operations, both to maximize the returns on infrastructure investment as well as to respond to shifting societal priorities, where increasingly high values are placed on environmental and aesthetic assets. These investments in institutions and hydraulic infrastructure were clearly a pre-condition to ***harnessing hydrology*** for sustained and broad-based growth and development.

The United States, for example, has invested trillions of dollars in hydraulic infrastructure. While these investments have been recognized as crucial to promoting growth, many of the largest federal investments in U.S. history were in fact made to curb the destructive effects of water – particularly in response to devastating floods (the US Army Corp of Engineers has spent about US$ 200 on flood management and mitigation since the 1920s, yielding an estimated US$ 700 billion in benefits.) Water resource development has had major positive growth impacts, but there have also been substantial social and environmental costs. These (often unforeseen) costs have fueled public debate on the importance of conservation and public consultation, and led to the adoption of environmental standards and social safeguard practices that are continuously evolving. Over the next ten years, some $21 billion per year will be spent to reach US environmental standards.[4]

In ***intermediate economies*** which are industrializing, much investment has typically taken place in water infrastructure. In some countries, substantial water investments are being made to promote growth (such as in hydropower and irrigation infrastructure), but the economy is still vulnerable to catastrophic impacts (such as those of floods and droughts.) In yet other cases, financing has been available to build infrastructure but institutional and human capacity is

[3] Preliminary results of a recent global study by Brown and Lall (2006) support this hypothesis.
[4] Jerome Delli Priscolli, USACE, personal communication.

inadequate or has not sufficiently adapted to manage water resources and new infrastructure effectively. These varied circumstances underscore the imperative of balancing and sequencing investments in the institutions and infrastructure required to effectively manage water resources. While it is generally accepted that countries initially will place a premium on physical capital investments, human capacity and institutions can take much longer to build and adapt. The proper balance and sequencing of these investments will therefore be dynamic and highly context-specific. Getting this balance right will be crucial for leveraging and sustaining growth that may now be ***hampered by hydrology***.

In India, for example, investments in water resources management, multipurpose hydraulic infrastructure and irrigation have contributed significantly to growth. Still, important opportunities remain for continued investment in infrastructure. Irrigation (irrigated districts average 25% poverty rates against 70% poverty rates in un-irrigated districts) and flood management and drainage infrastructure (the 2005 monsoons claimed about 400 lives and caused US$ 700 million in damages in Mumbai) are examples. The potential benefits of improved institutions are similarly significant. In Tamil Nadu, for example, robust management institutions that would allow a "flexible allocation" of water between uses could increase the state's agricultural production by 20% in 20 years, relative to fixed allocations.

In ***least-developed economies***, climate seasonality, variability and/or rainfall extremes are often marked, while the capacity, institutions and infrastructure needed to manage and mitigate these potentially major challenges are generally inadequate. Catastrophic hydrological events such as droughts and floods can have dramatic social and economic impacts with declines in annual GDP often exceeding 10% and tragic losses of life. What is less apparent is that, as a consequence of widespread expectations that these unmitigated catastrophes will recur, risk-averse behavior and disincentives to investment become pervasive. Such behavior can seriously undermine economy-wide investment and hence growth even in years of good rainfall. In many of the world's poorest countries, climate variability is high, water-related investments are relatively limited, and there is often a strong correlation between rainfall variability and GDP performance.[5] Where economic performance is closely linked to rainfall and runoff, growth becomes ***hostage to hydrology***.

In Ethiopia, for example, the current economic cost of hydrological variability is estimated at over one third of the nation's average annual growth potential, and these diminished rates are compounded over time. Yet, with much greater hydrological variability than North America, Ethiopia has less than 1% of the artificial water storage capacity per capita to manage that variability.[6] Clearly, substantial investments in infrastructure and in institutions are essential to meet this challenge.

[5] Brown and Lall (2006).
[6] World Bank (2006).

The Challenge of Water Security

The destructive quality of the resource in its natural, unmanaged state is arguably unique. We therefore define '*water security' to be the reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk to society of unpredictable water-related impacts.* Implicit in the notion of 'water security' is the idea of a 'minimum platform of water institutions and infrastructure.' Below this minimum platform, society and the economy are not resilient to the impacts of water shocks and/or unreliable water for production or livelihoods, and water is a significant obstacle to growth. The institutions, investments and management skills required for basic water security will differ across countries and across economic actors as a consequence of hydrology, the structure of the economy and risk aversion. A legacy of international rivers can also significantly affect the potential for managing and developing water to achieve growth and poverty alleviation.

Hydrological variability and extremes are at the heart of the challenge of achieving basic water security. This challenge will be compounded by climate change, and everywhere it will require significant adaptation. This will particularly be the case in poor countries which lack the institutions and infrastructure to manage, store and deliver their water resources, and where climate change will be superimposed on existing, and in some cases extreme, vulnerabilities. In many of the poorest countries, particularly in Sub-Saharan Africa, the currently unmanaged levels of climate variability are many times greater than predicted climate change. While many developed countries are focusing on mitigating climate change, developing countries are more focused on adaptation to current climate variability. In all cases, however, adaptive capacity – both social and physical – will need to be enhanced to protect the poorest and most vulnerable populations.

The Dynamics of Institutions, Infrastructure and Values

At all times, concomitant investments must be made in infrastructure and institutions. Over the past century or so there has been a change in this balanced relationship between water development and water management, due to an explosion in the development and worldwide adoption of new technologies and engineering capabilities. The institutions needed to manage these advances, however, have often been slow to adapt. The case of groundwater is illustrative, where the cultural practice and customary law of groundwater development was well-adapted to technologies which did not allow substantial groundwater abstraction from any but very shallow depths. With the introduction of motorized drilling rigs and pumps, allowing higher pumping rates from greater depths, a groundwater development revolution has taken place. Yet groundwater management policies and practices have not adapted in many countries, resulting in massive groundwater over-abstraction with serious and sometimes irreversible consequences.

Failure to understand the issue of balance and sequencing of infrastructure and institutions within the context of specific country circumstances may lead to poor investment choices. One potential danger is that most donor nations are strongly focused on water management as a priority, when in fact water management will provide little return when there is insufficient infrastructure with which to manage water and the priority of the client countries may well be for investment in this infrastructure. It is important that donor perspectives do not obscure the priorities of developing countries, and, at the same time, it is important that developing countries ensure the development and adaptation of water management institutions in parallel with their infrastructure investments.

Values and priorities also play into this dynamic. As countries grow and the welfare and dignity of their populations become more secure, their relative values and priorities often change. In many industrial countries, often following periods of significant economic growth, there tends to be a great deal of emphasis on re-operation or re-engineering of existing infrastructure systems to optimize performance and to meet evolving environmental and social priorities. Many developing countries, on the other hand, find their infrastructure stocks to be inadequate and therefore see an overarching imperative to invest in new water infrastructure in an attempt to reduce the destructive costs and increase the productive value of water in their economies.[7] The social and economic cost of not developing water, of simply maintaining the status quo, may also be much higher in developing economies where many people are physically vulnerable and live in life-threatening poverty. There is thus a clear willingness in many developing countries to face the trade-offs required to further these goals, mitigating their inevitable costs by the pragmatic application of social and environmental safeguards.

Alternative Development Paths

This path of shifting values is obvious, yet commonly unrecognized. In an increasingly globalizing world, there are pressures on developing country institutions to adopt developed country priorities and standards. Within this dynamic, however, the immediate and often extreme growth and poverty challenges faced by developing countries may not be fully acknowledged. At the same time, developing countries may not fully appreciate how greatly their values and priorities are likely to shift with growth, and therefore do not recognize this in their planning. Hydraulic infrastructure is characterized by its longevity and by its broad impact on the environments and societies in which it is built. Hamilton and Johnson[8] point out that much of the infrastructure built in the next 20 years will still be with us in 2050, and that some choices are irreversible or can be reversed only with great difficulty. In virtually all developing countries, demand for water,

[7] See SIWI (2005).
[8] Hamilton and Johnson (2004).

food and power continues to grow and there is no question that hydraulic infrastructure is needed.

Herein lies the challenge. Can the lessons of developed countries, enhanced by local and indigenous knowledge, provide insights into alternative management strategies and infrastructure designs and operations – or alternatives to infrastructure altogether – that still achieve water security, growth and poverty alleviation but have lower environmental and social impacts? Scale, site selection and operational characteristics need to be assessed from a long-term planning perspective, incorporating anticipated trends and emphasizing adaptability. This will ensure that future generations inherit institutions and infrastructure that can readily adapt to their evolving values. While no radical alternatives easily present themselves to the difficult task of managing and developing water resources through an evolving balance of institutions and infrastructure, there has been a steady process of learning and innovation that provides numerous lessons for following this basic path in a more sustainable and balanced way. A wide range of experience in water resource management and development, social inclusion and economic management provides a wealth of knowledge to guide more responsible growth.

Water, Poverty and the Burden of Proof

This paper raises important questions for development priorities and appropriate levels and mixes of investment in water resources, for program design, project economic analysis, and the potentials and constraints for developing countries to "leapfrog" their water institutions and infrastructure while avoiding the mistakes of the past. It suggests that we would expect to see a world where societies are poor where water is scarce or in excess, and/or water availability is highly seasonal and/or variable, because basic water security has not been achieved and a minimum platform is not in place. On the other hand, we can expect to see a world where societies are relatively rich where water is sufficient, widespread and reliable and water security was easily achieved – mostly in temperate climates with low rainfall seasonality/variability. There will of course be other reasons why societies are poor or rich, but we postulate that the significance of water investment is considerable – and little recognized.

This lack of recognition of the significance of water investment has serious consequences for poor countries. The focus of industrial countries is correctly on water *management* and *operations*, not on water *development*, because existing infrastructure stocks are adequate. This focus, combined with the controversy that often attends infrastructure investments, leaves little appetite among aid policy makers for supporting major water resources infrastructure development in poor countries and tackling the unavoidable tradeoffs that this entails. Opposition, particularly to the financing of dams for storage, hydropower or other purposes, can have significant political impact on the aid policies of donor governments and international organizations.

Yet there is very little discussion of the growth and poverty implications of diminished support for water infrastructure in poor countries – in particular of the costs of inaction – and of the moral hazard this entails for donor countries. The debate would benefit greatly from a better understanding of how developed countries have dealt with hydrological vulnerability, and how they have used strategic investments in water infrastructure to reduce risk, alleviate poverty and catalyze growth. The inevitable trade-offs involved in water development cannot be thoroughly assessed without an examination of the potential benefits of growth and poverty alleviation that can be derived from well-designed and well-managed water infrastructure.

At the same time, poor countries must not see infrastructure alone as a panacea. Without the development of appropriate water institutions, badly-managed infrastructure will likely not support growth, it (and its associated debt) may even forestall growth. The world is a different place in the 21st Century, and there is no doubt that the unforeseen and costly mistakes of the past can and must be avoided in the future. Water infrastructure, though essential, can and must be developed in parallel with sound institutions and with great attention to the environment and to equitable sharing of benefits and costs. And it can and must be robust and flexible, designed to allow its operation to adapt to changing values and priorities.

Unless these dynamics are recognized – by finance and planning decision makers in developing countries and by policy makers and aid administrators in developed countries – it will be extremely difficult for water security to be sustainably achieved in the world's poorest countries, severely constraining growth.

Almost all developed countries have followed a broadly similar path of early and extensive investment in water resources institutions and infrastructure to achieve water security and underpin growth. Today, most wealthy countries invest almost exclusively in improving water system operations and in institutional strengthening. Developing countries expect to have to follow the same path to water security and growth, and to have the support of developed countries as they do so. If this is not the case, and poor countries will not have the help of developed countries to invest in water resources infrastructure to achieve water security, but instead are asked to follow an alternative and arguably more benign development path, then where does the burden of proof rest that there is another path which is both affordable and demonstrated at scale? The 4th World Water Forum is an excellent opportunity to openly explore alternatives for more responsible growth, and further this important discussion.

1. Introduction

Water as a Source of Destruction and Poverty – or Production and Growth?

Water has always played, and continues to play, a central role in human societies. Water is a source of life and prosperity. It is an input to almost all *production*, in agriculture, industry, energy, transport, by healthy people in healthy ecosytems. Water is also a cause of suffering and devastation. It can be a force for *destruction*, catastrophically through drought, flood, landslides and epidemic, as well as progressively through erosion, inundation, desertification, contamination and disease. This destructive aspect of water, as a consequence of its extraordinary power, mobility, indispensability and unpredictability, is arguably unique. Achieving basic water security, harnessing the productive potential of water and limiting its destructive impacts, has been a constant struggle since the origins of human society. Many of the earliest civilizations, and particularly those on the floodplains of the world's great rivers, succeeded by harnessing water, thus increasing production and reducing the risk of destruction.

As then so today, water resources development and management remain at the heart of the struggle for growth, sustainable development and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in water infrastructure[9], institutions[10] and management capacity. It remains the case in many developing countries today, where investments in water development and management remain an urgent priority. In some developing countries – often the poorest – the challenge of managing their water legacy is almost without precedent. Yet, if these challenges are not met, we believe that sustainable growth and poverty eradication cannot be achieved.

Throughout history, water has also been a source of dispute and even conflict[11] between uses and between users at both local and larger scales. As water becomes ever more scarce relative to demand, there are emerging fears of transboundary waters becoming a source of conflict, constraining growth; conversely, there is also emerging experience of cooperation on transboundary waters, supporting regional integration as a driver of growth.

[9] Water infrastructure can be either manmade (dams, inter-basin transfers, irrigation, water supply, etc.) or natural (watersheds, lakes, aquifers, wetlands, etc.). See Emerton and Bos (2004).. The term 'physical capital' is used similarly.

[10] The term 'institutions' is used in a broad sense, to include capacity, organizations, policies, rules, and agreements. Global good practice suggests that these institutions can and should be designed to promote inclusion, accountability and equity.

[11] In fact the word 'rival' derives from the Latin *rivalis* meaning 'one using the same stream as another.'

Learning from Experience

In the second half of the 19th Century and first half of the 20th Century, all industrialized countries invested heavily in hydraulic infrastructure and institutions to facilitate their remarkable economic growth. However, in doing so they often incurred significant, unanticipated social and environmental costs. Many of the inevitable tradeoffs in water resources infrastructure development were poorly structured and/or projects were poorly implemented, to the detriment of project-affected communities and local natural environments. More recently, similar costs have been – and are being – incurred by developing and industrializing countries in their hydraulic infrastructure projects. In recent years a great deal of controversy has grown around water infrastructure development, and particularly large-scale water infrastructure, with significant resistance to such investments by affected and interested groups. This has led to a fairly general perception that water resources infrastructure development is *intrinsically* bad for the poor, bad for project-affected people and bad for the environment. This perception has become a barrier to financing water development, affecting countries with limited infrastructure (generally poorer), more than countries with mature infrastructure platforms (generally richer).

But there is no fundamental constraint to designing water development investments that ensure that local communities and the environment share real and early benefits while still allowing the economy and society at-large to benefit from the growth made possible by these investments. Moreover the poor are those who are generally most vulnerable to the destructive impacts of water, and those with the least opportunity to exploit the production opportunities that water can provide – suggesting that absolute inaction may in fact be intrinsically anti-poor. The great challenge that has so often gone unmet is to understand fully the range of costs, benefits, rights and responsibilities across all stakeholder groups, and to identify, design and implement projects that deliver their desired results.

There are many lessons from both good and bad experiences that can provide insights for all countries to strengthen institutions and management capacity, ensure better design of new (or operation of existing) water resource infrastructure, and strive for equity in the sharing of benefits. These lessons are leading to the adoption of international standards and safeguards that are continuously evolving in order to reflect our growing understanding of the full range of costs and benefits (direct, indirect and non-use benefits) that must be taken into account. These lessons may also lead to new development paths, both in terms of the way we manage our water resources and the way we manage water usage within our economies, which will not unduly constrain growth and development, yet will uphold evolving societal values regarding equity and the environment. The knowledge gained from experience, often at great environmental and social cost, must be used to help guide new policies, reforms

and investments to achieve growth in a more equitable and sustainable – and responsible – manner.

Responsible Growth and Water

There is a re-emerging consensus that water resources development and management are essential to generate wealth, mitigate risk, and alleviate poverty[12]; that poverty demands that many developing countries will need to make large investments in water infrastructure at all levels; and that this development must be undertaken building on the lessons of experience, with much greater attention to institutional development, to the environment and to more equitable sharing of benefits and costs. The challenge of "Responsible Growth" is to grow while at the same time embracing both environmental sustainability and social development.[13] A responsible path is particularly important in water development because, given the longevity of water infrastructure, many decisions will have long-term consequences. Furthermore many decisions – both decisions to act and not to act – may have irreversible consequences.

This paper

At the request of the Secretariat of the Fourth World Water Forum, this paper has been prepared to serve as a "reference point for discussion" on the theme of Water for Growth and Development. It seeks to raise a very basic question – how can water resources be managed and developed to promote growth and alleviate poverty in a responsible manner? The dynamics of water, growth and poverty are extremely complex, and highly dependent upon specific physical, cultural, political and economic circumstances. In many countries, the memory of the positive role that 'yesterday's' water investments played in underpinning growth has been lost, although the associated, often unanticipated, costs may still be being met. In other countries, the future costs of 'today's' water development are not recognized and irresponsible investments proceed, without adequate social and environmental safeguards.

The immediate goal of this paper is therefore to provoke discussion and strengthen understanding of the importance of water resources management and development[14] in enabling responsible economic growth and poverty alleviation – fully mindful of the fact that this is just one of many aspects that must be weighed and understood in managing water resources. The paper's broader objective is to contribute to a constructive, comprehensive dialogue that will help inform the

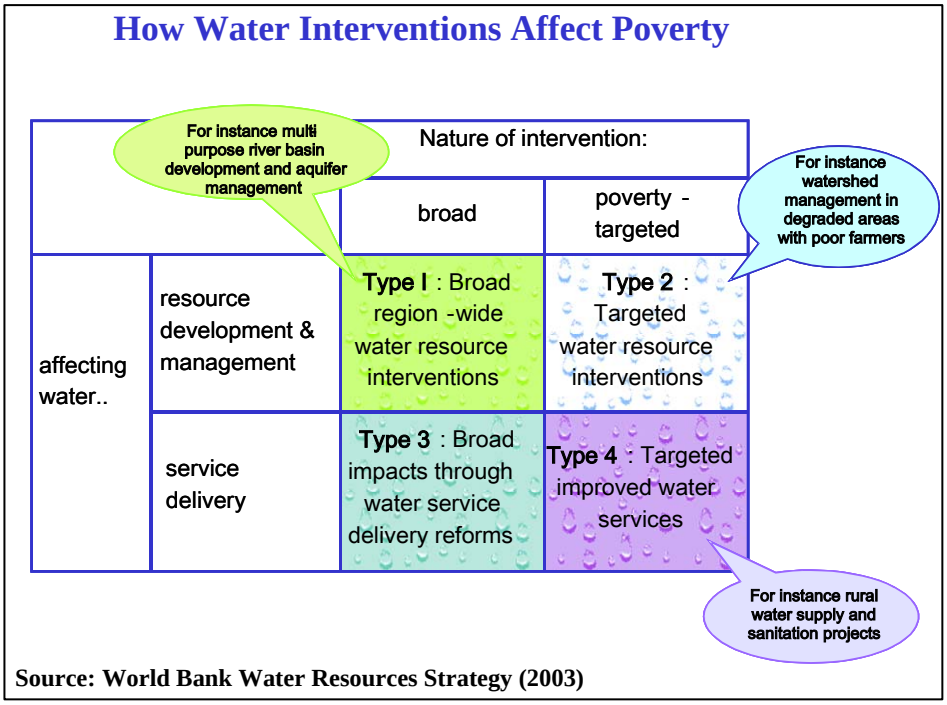
[12] See the policy conclusions of World Water Week 2005 (in SIWI 2005).
[13] Hamilton and Johnson (2004),
[14] The term "water resources management" is understood here to include both the management and development of water resources; this appears not to be a widely understood meaning. Water resources development refers explicitly to investments that control and deliver water resources.

difficult trade-offs inherent in water management, and assist decision makers in finding the most acceptable balance among human aspirations for growth and poverty alleviation, social and cultural integrity, and environmental sustainability.

2. Stories of Water and Growth

2.1 Water, Poverty and Growth

Four different mechanisms can be described through which effective water development and management play a fundamental role in sustainable growth and poverty reduction (see diagram). [15] First, broad-based water resources interventions, usually including major infrastructure such as major canal systems, dams and inter-basin transfers, provide national, regional, and local benefits from which all people, including the poor, can gain. Second, poverty-targeted water resources interventions are of major importance, such as investments to improve catchment quality and provide livelihoods for the poor, because it is usually the poor who inhabit degraded landscapes,. Third, broad-based water service interventions, such as those aimed at improving the performance of water utilities, user associations and irrigation departments, benefit everyone, including the poor. And fourth, poverty-targeted water service interventions, such as water and



[15] The World Bank (2003).

sanitation and irrigation services for the unserved poor, play a key role in reaching the Millennium Development Goals. In most developing countries, growth-oriented, poverty-reducing water resources strategies will involve action in all four of these areas.

Three scenarios

Are investments in water management and development a cause of growth, a prerequisite to growth, or a consequence of growth? In different countries, and even in the same country at different locations and points in time, the answers to all of these questions may be yes. Water provides a range of productive opportunities, so investments in water for agriculture, hydropower and industry, for example, can be seen as drivers of growth. Water resources management and development can also serve to protect societies from the destructive impacts of water, and meet basic human needs – serving as a prerequisite for growth. And effective water management can be seen as a consequence of growth where broader progress in governance, institutions and capacity have led to superior performance in developing and managing water infrastructure and institutions. The answer will therefore depend both on a country's hydrology and its level of economic development.

In all ***industrial countries***, the flows of almost all major rivers are regulated and managed, storing water for multiple uses, reducing peak flows, increasing low flows and protecting water quality, thus reducing the risk of water-related shocks and damage, increasing the reliability of water services for production, and reducing other negative impacts, such as disease. In many, but not all, industrial countries, climate seasonality, variability and extremes are limited in extent, implying that societies that did not have to combat an adverse climate regime had one less development barrier to overcome, facilitating earlier, easier growth. Preliminary results of a recent global study[16] support this hypothesis, finding a statistically significant relationship between greater rainfall variability and lower per capita GDP. Although varying widely, institutional aspects of water management are typically embedded in the political structure of governments and have often evolved over considerable time. Early and large investments have been made in bulk water infrastructure and in the human capacity required to operate and maintain these investments. In most cases, the infrastructure platform is mature and much greater emphasis is placed on water management and infrastructure operations, both to maximize the returns on infrastructure investment as well as to respond to shifting societal priorities, where increasingly high values are placed on environmental and aesthetic assets. These investments in institutions and hydraulic infrastructure were clearly a pre-condition to ***harnessing hydrology*** for sustained and broad-based growth and development.

[16] Brown and Lall (2006) examine seasonal and inter-annual rainfall variability as a factor in economic growth, and find in global data sets that rainfall variability is a key factor in national economic development.

In ***intermediate economies*** which are industrializing, much investment has typically taken place in water infrastructure. In some countries, substantial water investments are being made to promote growth (such as in hydropower and irrigation infrastructure), but the economy is still vulnerable to catastrophic impacts (such as those of floods and droughts) which continue to have major impacts on growth. In yet other cases, financing has been available to build infrastructure but institutional and human capacity is inadequate or has not sufficiently adapted to manage water resources and new infrastructure effectively. These varied circumstances underscore the imperative of balancing and sequencing investments in the institutions and infrastructure required to effectively manage water resources. While it is generally accepted that countries initially will place a premium on physical capital investments, human capacity and institutions can take much longer to build and adapt and there are many more areas of skill and knowledge applied to water resources management now than in the past – as engineers, economists, environmentalists and sociologists come together with stakeholders to design state-of-the-art water management. The proper balance and sequencing of these investments will be dynamic and highly context-specific.[17] Getting this balance right will be crucial for leveraging and sustaining growth that may now be ***hampered by hydrology***.

In ***least-developed economies***, climate seasonality, variability and/or rainfall extremes are often marked, while the capacity, institutions and infrastructure needed to manage and mitigate these potentially major challenges are generally inadequate. Catastrophic hydrological events such as droughts and floods can have dramatic social and economic impacts with declines in annual GDP often exceeding 10% and tragic losses of life. What is less apparent is that, as a consequence of widespread expectations that these unmitigated catastrophes will recur, risk-averse behavior and disincentives to investment become pervasive. Such behavior can seriously undermine economy-wide investment and hence growth even in years of good rainfall. At the sectoral level, we see many consequences of weak water resources management, such as unpredictable food production due to climate variability, health impacts of poor water supply and sanitation, unreliable electricity supplies, and a poor investment climate due to water-affected transport and energy infrastructure. In many of the world's poorest countries, climate variability is high, water-related investments are relatively limited, and there is often an apparently strong correlation between hydrology and GDP performance. This is particularly true in rainfed agrarian economies, and appears to be a significant phenomenon globally.[18] Where economic performance is closely linked to rainfall and runoff, growth becomes ***hostage to hydrology***.

[17] At the 2005 World Water Week there was a strong consensus that "What may be an appropriate approach and solution in one site and for a well defined problem is not necessarily benign in a wider setting." See SIWI (2005).
[18] Brown and Lall (2006).

These three broad types of water and growth scenarios are illustrated in the regional and national examples described in the following section. While the history of water in the growth and development of any country could fill volumes, that comprehensive task is far beyond the scope of this paper. Rather, these brief vignettes are offered to serve as points of departure for broader discussion. They focus on specific aspects of water resources management and development that may be particularly interesting or illustrative in a given country, and they include some extreme cases.

2.2 Growth Achieved in Developed Economies: Harnessing Hydrology

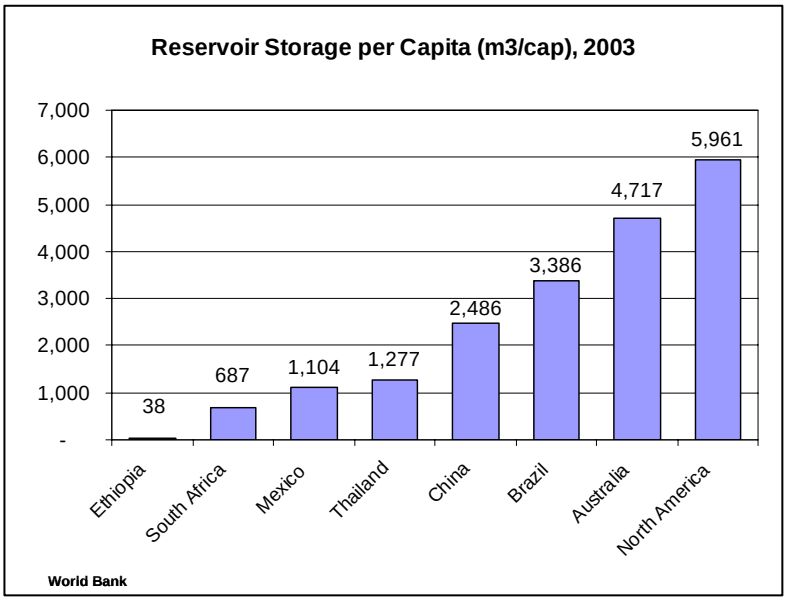
In North America

The United States has invested trillions of dollars in hydraulic infrastructure. While these investments have been recognized as crucial to promoting growth, many of the largest federal investments in U.S. history were in fact made to curb the destructive effects of water – particularly in response to devastating floods. The nation's founders saw investments in water development as a way to bring the nation together. Early canals catalyzed growth and trade, spawned innovation, and set the stage for western expansion of the country. In the early 20th century, the U.S. began to move to multiple uses of water as a means to bring affordable electricity to rural areas while protecting against drought and flood. In 1933, the Tennessee Valley Authority (TVA) was established to foster social and economic development in the Tennessee River Valley (southeastern United States) through the integration of a strong infrastructure, a healthy natural resource base, and human capacity. The infrastructure included a system of 42 large dams and reservoirs to support navigation, control floods, and produce power. This was coupled with an extensive transmission system to provide affordable electricity throughout the region. Intensive efforts to improve agriculture, land use, and forestry practices helped to restore and maintain a healthy environmental base, while technical assistance and small-scale credit programs provided people with the tools to improve their own lives. In one generation, the TVA brought one of the poorest regions in the U.S., and the world, out of poverty. It eradicated malaria, and provided virtually universal water, sanitation and energy access to an area where initial access rates were comparable to today's very poorest countries.[19] Similar programs were implemented in other river basins, such as the Colorado, often driven by charismatic politicians.[20]

[19] Miller and Reidinger (1998).

[20] "Of all the endeavors I have worked on in public life, I am proudest of the accomplishment in developing the Lower Colorado River. It is not the damming of the streams or the harnessing of the floods in which I take pride, but rather in the ending of the waste of the region. The region – so unproductive in my youth – is

It is interesting to examine historical investments in river regulation and water storage in North America. To protect against the devastating effects of flood and drought and enable economic growth, over 6,000 cubic meters of reservoir capacity per capita has been installed (this is a national average, with much higher per capita storage in the semi-arid western U.S.) – compared with 550 m^3/capita in intermediate, semi-arid Morocco, and less than 40 m^3/capita in Ethiopia, a nation wracked by flood and drought.[21] Hydraulic infrastructure on the Colorado River, including Hoover and Glen Canyon dams, has underpinned growth in the enormously productive economic development of the southwest, in a region of aridity and variability. The Colorado River now has some 1400 days of storage, while the Indus has roughly 30.[22] Nationally, the US Army Corps of Engineers has spent about $200 billion on flood management and mitigation since the 1920s. This investment has yielded an estimated $700 billion in benefits, and mitigated the impact of floods on the US economy to such an extent that flood damages have remained below 0.5% of GDP since that time.[23]



now a vital part of the national economy and potential. More important, the wastage of human resources in the whole region has been reduced. Men and women have been released from the waste of drudgery and toil against the unyielding rocks of the Texas hills. This is the true fulfillment of the true responsibility of government." U.S. President Lyndon Baines Johnson, 1958.

[21] World Bank, based on data from ICOLD World Register of Dams (2003) .

[22] This estimate is based on live storage capacity and average annual flows.

[23] Jerry Delli Priscoli, USACE, personal communication.

Local Actions for Flow Restoration in the Pacific Northwest of the United States

Water Trusts. In the Pacific Northwest, the public trust model as developed first by land trusts was extended to water rights through the Oregon Water Trust in 1993 and further extended in subsequent years to the Washington and Montana Water Trusts. These organizations have raised millions of dollars from members and interested foundations for the purposes of engaging in projects and transactions that return water rights to the public trust, that is, water rights that are dedicated instream either permanently or for a period as a lease.

The Deschutes River Conservancy is a private nonprofit organization that works with federal agencies on ecological restoration projects, sharing costs on a 50/50 basis. The DRC mission is to restore streamflow and improve water quality through the use of voluntary market-based economic incentives, acquiring and protecting water rights instream. Since 2000, it has increased local awareness and appreciation for the value of water rights through payments to irrigation districts for water conservation projects and by providing a market for temporary and permanent instream transactions for water right holders. These programs have trebled flows in the main stem Deschutes and restored 50% of target flows for fish and wildlife in critical dewatered tributaries.

The Columbia Basin Water Transactions Program was initiated by the Bonneville Power Administration in 2003 to explore innovative strategies, including water rights transactions for environmental flows, as part of its obligations under the National Marine Fisheries Service Biological Opinion on the Columbia River System. The program is administered by the National Fish and Wildlife Foundation, with 11 local entities from Oregon, Washington, Montana, and Idaho that have qualified to participate in the program.

Source: Aylward (2005).

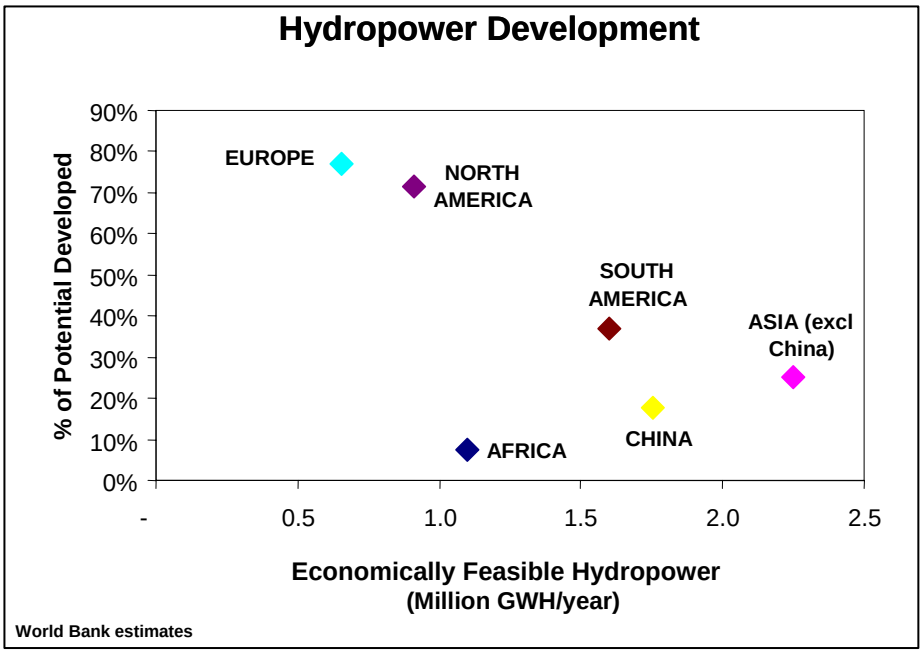
While this large scale infrastructure development has had major positive growth impacts, there have also been substantial social and environmental costs. There are serious ongoing concerns, for example, regarding the sustainability of current water-use patterns, the need for demand management, dam re-operation to manage in-stream flows, etc. There are many, recent and innovative local actions to meet these challenges (examples are presented in the box above). The trade-offs between growth and environmental and social change associated with infrastructure development fueled public debates in the U.S. on the importance of conservation, environmental standards and public consultation, debates which continue today. Environmental standards and processes for stakeholder consultation were established in the U.S. by the 1969 National Environmental Policy Act (after a large portion of the current infrastructure stock was built), and have since evolved under the Environmental Protection Agency (EPA).

Canada, a nation with the world's greatest endowment of fresh water where hydropower resources remain a backbone of the economy, is now revisiting the operations of its hydraulic infrastructure to meet evolving environmental and social priorities. Agreements regarding infrastructure development on transboundary rivers and lakes shared with Mexico and Canada have initiated dialogues that resulted in the establishment of cooperative intergovernmental institutions. These ongoing debates have created, and no doubt will continue to

create, tensions between different stakeholder groups and water users – but these debates are a key to learning from mistakes and finding a more balanced way forward.

In Western Europe

Across most of the region a predominantly temperate climate means that the risks posed by water have always been relatively small. Still, extensive investment in water storage and river regulation to supply and protect industrializing cities, the engines of rapidly growing economies, led to a relatively mature platform of hydraulic infrastructure by the early 20th Century. The Netherlands is a special case where human settlement and survival has long been determined by sophisticated water infrastructure – the dykes and polders of the 'low country', and sophisticated institutions – the water parliaments that were the foundation of modern Dutch democracy.



Hydropower investment is one interesting aspect of European water resources development. Significant investments have been made in Europe to develop hydropower resources, with over 70% of potential developed, in contrast to some 5% of Africa's hydropower potential that has been developed. France has about 26,000 MW of economically viable hydropower generation potential and has developed 25,500 MW of this. In Norway, almost all power needs are met from the 28,000 MW of installed hydropower capacity, with over 23,000 kWh per capita per year of hydroelectric power generated (some going into regional power grids). This figure is about twice the electric power consumed per capita in the USA, 10

times the world average, almost 80 times that of Ghana, and roughly 750 times that of Ethiopia.[24]

In recent years, at both national and European level, there has been growing recognition of the imperative to protect the environment and water quality as an integral part of water resources management. In 2000, the EU Framework Directive on Water Policy (Directive 200/60/EC) was adopted. This discourages the development of new dams where environmentally and economically feasible alternatives exist.

In Asia/Australasia

In Japan, water and culture are closely interwoven, with a long history of water management for transport and flood mitigation. The flood plains of Japan, despite their vulnerability, host some 40% of the population and 60% of the economy's productive assets are located in these areas. Preliminary data show that flooding, caused by heavy seasonal rains as well as typhoons, had serious impacts on the Japanese economy as recently as World War II, with single-year flood shocks occasionally exceeding 20% of GDP. From 1950 to 1975, some ¥ 2 trillion was invested in river infrastructure (similar to the investment in railways). Since the 1970s, a period of extraordinary growth for the Japanese economy, the impacts of flood on the Japanese economy have not exceeded 1% of GDP in any year.[25] Even with this infrastructure stock, US$ 9 billion of public funds continue to be spent annually on flood management and mitigation.

The story of Australia is very different. Here, aridity and variability supported a pastoral lifestyle of indigenous people that was changed dramatically by the import of skill and capital in the 19th Century. Heavy investments in water institutions and water infrastructure through the 20th Century underpinned the modern growth of the nation, providing power for industry,[26] water for human settlement, and massive agricultural and livestock production. This remarkable development was not without cost, however. Increasing environmental concerns such as the blue green algal bloom along 1000 km of the Darling River in 1991, soil salinization resulting from intensive irrigation, growing activism and evolving societal values are now placing a high priority on managing environmental assets, with water quantity and quality markets emerging as key instruments for doing so.

2.3 Growth Constrained in Intermediate Economies: Hampered by Hydrology

[24] Hydropower potentials are derived from the International Journal on Hydropower & Dams World Atlas & Industry Guide 2005.
[25] Kenzo Hiroki, Japan Water Forum, pers. comm..
[26] Tasmania described itself as the 'greatest hydroelectric state of the Commonwealth'

In South Asia

Initial investments in India in water resources management and multipurpose hydraulic infrastructure had massive regional impacts with large multiplier effects on the economy.[27] There are also direct correlations between investments in irrigation and significant declines in poverty – irrigated districts average 25% poverty rates against 70% poverty rates in unirrigated districts. And irrigation is broadly credited with sustaining the green revolution in India. The benefits of improved water resources management and institutions are similarly significant. In Tamil Nadu, for example, robust management institutions that would allow a "flexible allocation" of water between uses could increase the state's agricultural production by 20% in 20 years, relative to fixed allocations.[28] De-linking the economy from the monsoon, however, with a combination of infrastructure, water management and economic diversification, has long been a recognized challenge. India's Finance Minister said that, in the 1980s "every one of my budgets was largely a gamble on rain."[29] A recent leader headline in India was "Growth surge: no longer a gamble on Monsoon,"[30] describing the shift out of agriculture and the expansion of manufacturing, communications and transport which is making the structure of the economy less vulnerable. Still, the variability of rainfall in recent years continues to take a heavy toll across many regions of India, and the 2005 monsoon claimed about 400 lives and caused $700 million in damages in Mumbai.[31]

In South Africa

South Africa, characterized by high climate variability, is an interesting intermediate case where apartheid-era water investments were made to ensure economic resilience for large-scale commercial farming, mining and financial services in the nation's heartland, while the rest (most) of the country had little water infrastructure. The Vaal River System, situated in a semi-arid region with highly variable rainfall and runoff, includes inter-basin transfers with seven other rivers systems and 16 major dams; it also provides cooling water for power stations that generate about 85% of the nation's electricity.[32] In seven of South Africa's nine provinces, more than 50% of its water is provided by inter-basin transfers. South Africa has about 700 m^3/cap in artificial storage, about 12% of the 6,000 m^3/capita of North America. Arguably, however, these figures may be more similar to those in North America in that South Africa's storage investments were made to serve only a small proportion of the population. This strategy essentially provided full water security to minority-dominated growth poles within the economy, leaving the bulk of the population highly water vulnerable and without the essential services needed to grow and prosper. This was clearly

[27] See Bhatia and Malek (2003) on the case of Bhakra dam, and Peter Hazell (IFPRI) on irrigation in Tamil Nadu.
[28] John Briscoe, The World Bank, pers comm.
29 Financial Times, June 18, 2001.
30 The Economic Times, February 18, 2005
[31] BBC News website. Payal Kapadia, August 2, 2005.
[32] Basson et al, 1994.

inequitable, but its effect was massively reduced vulnerability and strong investment incentives in these growth poles. Today, with pluralism and democracy, this wealth is being spread, high growth rates are being sustained and there are major shifts in values. For example, in recent legislation, specific flow allocations in each river basin are mandated for basic services to the poor and for in-stream environmental flows, before other allocations are considered.

In Poland

Poland's Odra River is dangerously flood prone. Rising in the Carpathian Mountains it flows north through Poland and Northern Germany into the Baltic Sea. Its valley is densely settled and subject to seasonal flooding, with twelve large floods recorded in the 20th century. Severe summer floods in 1997 caused direct damage of about US$ 2.3 billion. 700,000 homes were flooded and 110,000 people evacuated. The disruption had longer term psychological as well as economic impacts on people's lives. The Polish authorities responded quickly, with a US$ 200 million flood recovery program that supported both infrastructure reconstruction and the development of improved weather forecasting, flood warning and river basin management planning. In parallel, the government of Poland has developed a comprehensive strategy for modernization of the flood protection system in the Odra River basin. The program of investments, whose cost is estimated at US$ 2.3 billion, includes construction of passive and active flood management systems, protection of the natural environment and water quality, flood recovery, preventive land use planning and ecosystems restoration, increase of wooded areas, and continued use of the river for navigation and power generation. The program will protect 2.5 million people, their property and businesses from floods. It has been designed with a high level of local consultation and environmental and social safeguards and has an economic rate of return conservatively estimated at 17%.[33] This demonstrate that even in middle-income countries with relatively well-developed water infrastructure, there are clear social, environmental and economic benefits from investing in balanced programs of improved river basin management and development.

In Mexico

Mexico has a strong history of water management and institutions, with a modern water law, a national water authority, water user associations, basin councils, a water rights system, and an incipient water market. Still, water is increasingly becoming an effective constraint in various regions of Mexico, impacting the competitiveness and sustainability of the broader economy[34] and the poor in particular. Mexico's population has grown fourfold in the past fifty years. Nearly 80 percent of that population is now concentrated in Mexico's northern and central areas, which account for over 80 percent of GDP, over 90 percent of irrigation, and 75 percent of industrial activity. The consequent increase in demand for water resources, exacerbated by inadequate infrastructure and centralized

[33] World Bank.
[34] *Economic Assessment of Policy Interventions in the Water Sector*, World Bank, Washington, DC, 2005.

institutional arrangements, has led to a growing water crisis. The country's current challenges also include: low water productivity in irrigation; over-exploitation of groundwater in the most important aquifers; and extensive water pollution. Inappropriate water pricing has sustained inefficient irrigation practices and promoted the use of scarce water resources for the irrigation of low-value crops. Although some irrigation is shifting to water-saving techniques, the shift is limited, and the crop mix remains largely the same because prices do not reflect the scarcity of water. Intensive groundwater pumping has led to the overexploitation of 100 of the country's 653 aquifers. Groundwater over-extraction is estimated at almost 40 percent of total groundwater use. The value of the over-extracted groundwater in agricultural production alone is estimated at more than US$1.2bn or 0.2 percent of GDP. Groundwater pumping is encouraged by highly-subsidized electricity tariffs. The annual financial cost of electricity subsidies is estimated at US$ 300 million, and represents only a fraction of the full economic cost because environmental degradation is not adequately valued. The depletion of groundwater aquifers and inefficient use of agricultural water compromises growth in Mexico's most dynamic economic regions.

2.3 Growth Stalled in Developing Countries: Hostage to Hydrology?

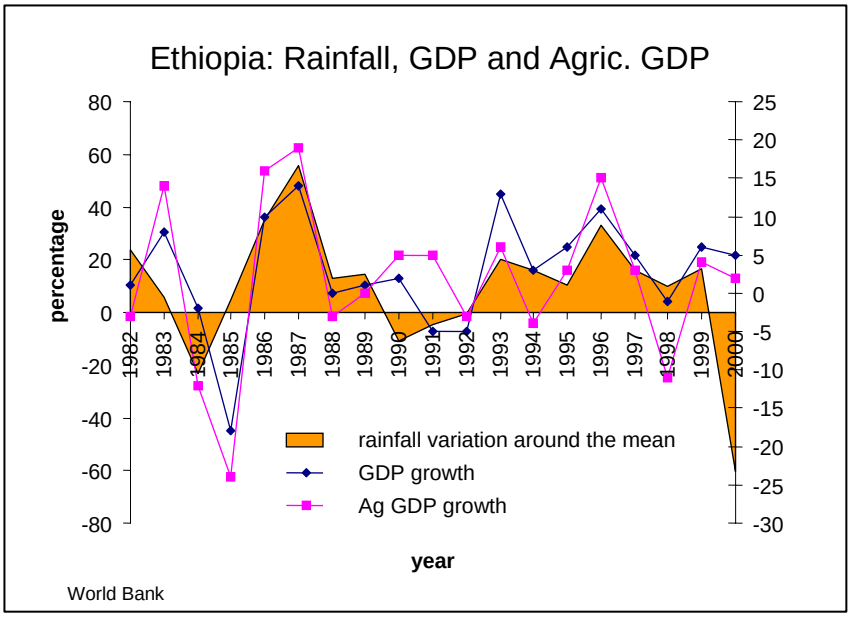
In Ethiopia[35]

Hydrological variability seriously undermines growth and perpetuates poverty in Ethiopia. The economic cost of hydrological variability is estimated at over one third of the nation's average annual growth potential, and these diminished rates are compounded over time. Yet, with much greater hydrological variability than North America, Ethiopia has less than 1% of the artificial water storage capacity per capita to manage that variability. Economy-wide models that incorporate hydrological variability in Ethiopia show that projections of average annual GDP growth rates drop by as much as 38% as a consequence of this variability.[36] In Ethiopia, so sensitive is economic growth to hydrological variability that even a single drought event within a twelve year period (the historical average is every 3-5 years) will diminish average growth rates across the entire 12-year period by 10%. The effects of hydrological variability emanate from the direct impacts of rainfall on the landscape, agricultural output, water-intensive industry and power production. Because Ethiopia lacks the water resources infrastructure and institutions to mitigate hydrological variability directly, and it lacks the market

[35] "Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia", The World Bank, 2006.

[36] This estimate is based on the results of a stochastic, economywide multi-market model that captures the impacts of both deficit and excess rainfall on agricultural and non-agricultural sectors. The results show growth projections dropping 38% when historical levels of hydrological variability are assumed, relative to the same model's results when average annual rainfall is assumed in all years (which is the standard modeling assumption.) Ibid.

infrastructure that could mitigate the economic impacts of variability by facilitating trade between affected (deficit) and unaffected (surplus) regions of the country, impacts are transmitted and even amplified through input, price and income effects onto the broader economy. The overall impact is that Ethiopia's economic growth is tied tightly to the rains (see figure).[37]



In Yemen[38]

Water and poverty are closely linked in Yemen. Groundwater overdraft, degradation of watersheds and low access to safe water and sanitation are all principal causes of poverty in the country. Yemen has no perennial surface water, and depends entirely on rainfall, groundwater and flash flooding. By world standards, Yemen is a country poorly-endowed in water resources. Even compared to other countries in the Middle East, Yemen has among the lowest rates of per capita freshwater availability (150 m^3/cap/year) and one of the highest rates of water use in agriculture. Moreover, this relative water scarcity is exacerbated by significant physical and temporal variations**.** With population

[37] This graph presents a correlation that does not necessarily prove causality. An interesting question raised by this graph is why excessive rains are not associated with lower GDP growth. One possible explanation might be explored from the case of Kenya (see World Bank 2005.) Here the majority of economic costs from drought are losses in agricultural incomes, whereas the economic costs of floods manifest in infrastructure damage (i.e., roads and bridges.) In the calculation of GDP, agricultural losses directly diminish GDP. However infrastructure damage, if it were immediately repaired, could be recorded as investment in the national accounts which would actually increase GDP and explain why excessive rains appear to be associated with strong growth.

[38] Republic of Yemen Country Water Resources Assistance Strategy, World Bank, 2005

projected to double, water availability per capita will decrease 35% by 2025, well below levels generally considered to indicate severe water stress. Yemen is enduring a water crisis that ranks amongst the worst in the world. There is firm evidence that Yemen has been overdrawing or "mining" its groundwater resources for many years. Groundwater use began to exceed recharge in the mid-1980's with more than 80% of abstraction going to irrigated agriculture. In agriculture and irrigation the status quo appears unsustainable and anti-poor. Water access is inequitable, and de facto water rights patterns and water mining practices exacerbate inequalities. With the continued mining of groundwater in all regions of Yemen, some areas will almost certainly lose their economic viability, and even their drinking water supplies may become inadequate, causing displacement and resettlement. At the present rate of depletion, the sustainability of livelihoods, especially in a country as poor as Yemen, is jeopardized. Government policies promoted the rapid development and utilization of water resources. In the early 1990s the severity of the water shortage and a growing fiscal crisis became evident. Now, the scarcity of water and economic crises are forcing change.

2.4 Water-Using Sectors and Growth

Sectoral Perspectives

Water resources management encompasses water in all its uses, across all sectors. The primary thrust of this paper is on the economy-wide relationship of water with growth and poverty, which is the aggregate of the effects of water management policies and practices, as well as the contributions to growth of, and inter-relationships between, water use *within* individual sectors (such as water supply and sanitation, power, irrigated agriculture). It is clear that water use within individual sectors contributes significantly to this relationship, with each having its own welfare, growth, equity and gender implications. For example, decisions regarding whether water supply and sanitation services are to be provided, their location, cost and reliability, can all affect the spatial patterns and rates of growth that result from those investments. This will also be the case for investments in hydropower, navigation and industrial water services. In agriculture, the balance between traditional subsistence agriculture (which generally targets the very poor and provides greater employment opportunities) and highly intensive production (which generates higher value-added to a smaller immediate beneficiary group) will significantly affect the market value of agricultural production and the distribution of these gains. Investing in water for the environment[39] will also have growth and poverty implications. These natural resources are generally most heavily relied upon by women and the poorest segments of society, and it is they who are most vulnerable to their deterioration.

[39] While the environment is not considered an economic "sector," it has investment and water requirements comparable to those of traditional economic sectors. We therefore include it here.

Management of aquatic ecosystems is now widely accepted as an imperative not only as sound (and cost effective) natural resource management, but also an imperative for sustaining the livelihoods and well-being of the poorest populations. In addition, it is increasingly recognized that conserving and enhancing 'natural infrastructure' (i.e., aquifers, watersheds, lakes and wetlands) is a sound investment, complementing and in some cases substituting for artificial storage, regulation and treatment infrastructure, serving the needs of water-using sectors as well as ecosystems.

Valuing the Zambezi's Wetlands as an Infrastructure Alternative. Restoring wetlands can increase storage by recharging groundwater, regulate stream flows (thus mitigating floods and drought), reverse changes in the microclimate, and protect and improve water quality through purification and treatment. Recreational and tourism activities can also contribute to economic growth. However, valuing the associated contribution of wetland biodiversity/and critical habitat benefits is often difficult, especially when based on non-use values. A rough assessment by the World Conservation Union (IUCN) on the economic value of wetlands in the Zambezi Basin in Southern Africa suggest that there was a net present value of US$3 million in reducing flood-related damages, US$16 million in terms of groundwater recharge, and an estimated US$45 million in water purification and treatment services.

"Value: Counting Ecosystems as Water Infrastructure." Emerton and Bos. 2004.

Inter-sectoral Perspectives

It is also important to understand the impacts of water use *across* sectors. Water policies and reforms and infrastructure investments in one sector rather than another will have very different consequences for growth and poverty alleviation. For example, irrigation and household water supply and sanitation services have traditionally been seen as pro-poor, whereas, investing in hydropower and industrial water supply has traditionally been seen as a strategy for economic diversification and growth. Clearly these are very broad generalizations, but inter-sectoral water resources allocations will affect the structure of economies, patterns of development and growth (with associated equity and gender implications), and the environment. The allocation of water between the agriculture, power, industry and services sectors will enable or constrain their relative growth, and give rise to very different economies over the medium term, with differing welfare impacts both in terms of overall growth and the distribution of this growing wealth. Moreover, it is quite often the case that the allocation of water and water investments between sectors is the result of political economy rather than deliberate development policy, allowing the "capture" of water resources by powerful interests in ways that hinder opportunities for more effective resource management.

Water, Poverty and Gender

Local level social structures often determine individuals' access and vulnerability to water. Furthermore, gendered assumptions in policy decisions about water uses and users impact the vulnerability and productivity of poor women and men across a range of sectors.

To understand the dynamics of gender in water and growth, it is necessary to identify and value the often under-enumerated activities of women as sources of economic growth. To illuminate the gender impacts of inter-sectoral water allocation policies, women's and men's shares of employment and income in water using sectors must be disaggregated (the "gender intensity of production", for example, is known to be particularly high in agriculture). It is also important to understand the degree to which water-led growth impacts particular classes, especially by landholding status. Finally, any such productive investment towards growth and poverty reduction is also predicated upon sufficient allocation to domestic water supply to ensure human health, a sphere that has been largely the gendered responsibility of women and girls.

Another key policy area is water rights, where there are significant gender and poverty implications. 'Minor' water uses, such as livestock watering, homestead gardens, fisheries and small-scale industry, are often crucial elements of poor households' livelihood strategies, and such multiple uses easily escape notice during negotiations on tradable water rights. Particular care is needed when title criteria are defined during irrigation and resettlement schemes to ensure equitable access to land and water resources for women.

In agricultural water use, the gender division of labor has implications for water management, agricultural productivity, and growth and poverty impacts. The water preferences of women and poor men will often vary from those of landed male farmers, in timing, quality, and duration, underscoring the importance of women's and tenants' participation in water users associations.

Through attention to the varied needs and institutional locations of all water users, water resources investments can be made more effective means of supporting sustainable and equitable water use for growth and poverty reduction.

Source: Drawn from Kuriakose, et. al (2001), Meinzen-Dick and Bakker (1999), Van Koppen (2000), and Zwarteveen and Neupane (1996).

3. Water Security and Growth

3.1 Water Security: Growth Enhanced, Not Undermined

Water Security

The terms 'food security' and 'energy security' are widely used to mean reliable access to suffic ient supplies of food or energy to meet basic needs of individuals,

societies, nations or groups of nations.[40] The term 'water security' has been used in the literature with an equivalent meaning.[41] It is worth noting that in some cases food and energy security will be achieved through self-sufficiency, in other cases they will be traded (imported) to ensure adequate supplies. With water, however, trade is more complicated. Water itself can be traded within transboundary water systems or through physical transfer schemes such as tankering or pipelines, which are relatively costly; or traded as 'virtual water'[42] by importing products such as food which embody large amounts of water as an input. A more striking difference, however, is that unlike food or energy, it is not just the *absence* of water but also its *presence* that is a threat. Unmanaged water resources, for example through flood, present a genuine threat to human security.

In this paper we therefore use the established definition and extend it to take account specifically of the potentially destructive impacts that water can have. This destructive quality of the resource in its natural, unmanaged state is arguably unique. We therefore define *'water security' to be the reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk to society of unpredictable water-related impacts*. Such impacts could arise from marked rainfall and runoff variability, including the extremes of drought and flood, natural or anthropogenic contamination, water-induced landslips, etc.. Societies and nations make initial water investments in bulk water resources regulation and storage, in water supply for human settlement and industry, food and energy production, and in the associated institutions needed to manage the resource and related infrastructure in order to reach a perceived level of 'water security.' Once an acceptable level of water security has been achieved, if further investments are made they tend to be focused more on growth enhancement, rather than on meeting unfulfilled basic needs and mitigating risks. Further investments will increase water security, which is a dynamic condition: different in different parts of the world (reflecting geographic, climatic, social, epidemiological, economic and political factors) and changing over time as many of these factors shift with development.

A Minimum Platform of Water Institutions and Infrastructure

Implicit in the notion of 'water security' is the idea of a 'minimum platform of water institutions and infrastructure'. Below this minimum platform, society and the

[40] The Rome Declaration on World Food Security and World Food Summit Plan of Action (11996) defines food security in the following way, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." It should also be noted that food security is to a large extent related to water security, although this link can be bypassed through food imports.

[41] Water security has been defined as an overarching goal where: "…every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the environment is protected and enhanced" (Global Water Partnership 2000).

[42] See Allan (2001).

economy are not resilient to the impacts of water shocks and/or unreliable water for production or livelihoods, and water is a significant obstacle to growth. Water security will be achieved with the acquisition of an appropriate level and combination of management capacity and infrastructure investment. Thus, when 'basic water security' is achieved, societies are resilient to the impacts of water – such that a lack of access to water-related services and vulnerability to water-related impacts (drought, flood, disease etc.) no longer create significant obstacles to growth. Until 'basic water security' is achieved, the scale of social impacts (e.g. morbidity, mortality, resource conflict) and related economic impacts (e.g. from institutional failure, production inefficiencies, disaster shocks) can be such that the economy, environment and society are significantly affected, and economic growth cannot be reliably and predictably managed.

Institutions and Infrastructure

Institutions are defined broadly to include governance, capacity, organizations, policies, regulations and incentives. Different water institutions address many issues, ranging from water allocation, quality, rights and pricing, to asset management and service delivery, and their performance will be influenced by broader governance and human resource capacities. For effective water management, institutional design needs to ensure inclusion, accountability and equity, and be flexible enough to adapt to change – such as in social policies and technologies. Strong institutions and sustainable governance will also directly contribute to appropriate investment in, and proper operations and maintenance of, sound and reliable water infrastructure. Infrastructure investments may be needed at all scales. Natural assets can perform infrastructure functions, so investments in watershed, lake, riverbank, watershed and wetlands management is included. Small-scale water resource infrastructure might include small check dams, weirs and bunds. At the other end of the scale, investment in bulk water management infrastructure might include multipurpose dams for river regulation and storage, or inter-basin transfer schemes. Infrastructure for service provision would also likely be needed at all scales, from major municipal water supply and sewerage schemes to community- and household-managed water and sanitation systems, or from large hydropower plants to small, run-of-river schemes. Sound infrastructure investment choices will be made as an outcome of an analysis of all feasible options and be governed by social and environmental safeguards.

Lakes – Their Values and Challenges

Lakes contain 90 percent of the liquid freshwater on the earth's surface and are found on all continents of the world, even Antarctica. These natural assets are critical elements of the water cycle; they sustain aquatic biodiversity and provide livelihoods and social, economic, and aesthetic benefits that are essential for the quality of life in and beyond lake basin communities. In addition, constructed reservoirs contain over 14 percent of global annual runoff.

Lakes and reservoirs provide many services which include: water for household use, industry, livestock and irrigation; storage for hydropower generation; buffering against floodwaters and protection against droughts; artisanal and commercial fisheries and aquaculture; transportation; sites for recessional cropping and grazing; sinks for pollutants, including sewage and inflowing sediments; tourism based on biodiversity, scenery, or sporting activities; cultural and religious uses; and sites for biological diversification.

Due to the heavy pressures being placed on lake and lake basin resources, most lakes are experiencing a decline in their resource values. A recent report on world lakes found that all 28 lakes included in the study are experiencing multiple problems. Sound institutions and, sometimes, sustainable infrastructure are needed to improve the status of lakes. Sound institutions have effective and fair rules governing use of resources, involvement of all affected stakeholders, collection and application of high quality information, and access to sufficient resources for long-term operations and maintenance. Technological solutions can lead to rapid improvements in the environmental status of lakes—most notably with sewage treatment plants. However, these technological solutions are usually not sustainable if the elements of good governance are not in place.

Adapted from: Managing Lakes and their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders (2005). ILEC, Japan.

The Right Balance: Investments in Institutions and Infrastructure

These two types of investment must be made in concert – the relative weight or priority of investments in infrastructure versus institutions and management is a question of degree only. Infrastructure will not deliver high, sustained returns if it is not well managed, and managers will not be able to optimize the use of the resource without adequate (natural or manmade) infrastructure. We believe it is an important exercise to explicitly separate the two, however, in order to ensure that the balance and sequencing of investments is appropriately targeted to meet the specific needs of each country, basin or local context. Once conceptualized as complementary, it is most effective to integrate investment with institutional development and reform programs and ensure they are mutually reinforcing.

3.3 Determinants of Water Security

The institutions, investments and management skills required for basic water security will differ across countries and across economic actors as a consequence of hydrology, structure of the economy and risk aversion. Global climate change is also likely to increase the complexity and costs of ensuring water security. A nation's hydrology will clearly affect the level of institutions and investment required to achieve water security. The absolute levels of water resource availability, its inter- and intra-annual variability and its spatial distribution, coupled with the demand for water, will largely determine the institutions and the types and scale of infrastructure needed to manage, store and move the resource. The resilience of the structure of the economy to water shocks, together with societal resilience and risk aversion will also be determinants of the level of investment required for specific countries to reach the tipping point of water security.

Hydrologic Legacy

An 'easy' hydrologic legacy. Relatively low rainfall variability, with rain distributed throughout the year and perennial river flows sustained by groundwater baseflows, results in hydrology that is relatively 'easy' to manage. In temperate parts of the world, much of which are now industrialized, achieving a basic level of water security was straightforward and required comparatively low levels of skill and investment (primarily because water was sufficient, widespread and relatively reliable). Once this was achieved, growth was able to proceed without water being a significant constraint. As infrastructure platforms grew, returns from new water investments gradually diminished, water became a reliable input to production and risks fell to acceptable levels. At this point, the need and incentives for developing new infrastructure are relatively low, while the returns from, and the incentives for, better managing and operating existing assets are likely to be high.

A 'difficult' hydrologic legacy. 'Difficult' hydrologies are those of absolute water scarcity and, at the other extreme, low-lying lands where there is severe flood risk. Even more difficult hydrology is where rainfall is markedly seasonal – a short season of torrential rain followed by a long dry season requires the storage of water. More difficult still is high inter-annual climate variability, where extremes of flood and drought create unpredictable risks to individuals and communities through to nations and regions and require over-year storage. Perhaps most difficult of all is a combination of extreme seasonality (intra-annual) and variability (inter-annual) – characteristics of many of the world's poorest countries today. With increasingly 'difficult' hydrology, the level of institutional refinement and infrastructure investment needed to achieve basic water security becomes significantly greater than in temperate (and less variable) climates. Perhaps as a direct consequence of the scale of this challenge, 'basic water security' has not

been achieved in many poor countries and water remains a key constraint on growth, an unreliable input to production and the cause of major economic shocks. While the returns to society from investing to achieve water security (essentially de-linking water from growth) could be very high, there is generally insufficient national wealth to invest. Taking this argument further, we postulate that societies in areas of water scarcity and/or high climate variability have remained poor[43] and in a low-level equilibrium trap, in part because it has not been possible for them to make the comparatively large investments needed to achieve water security. The global findings of Brown and Lall[44] support this hypothesis by confirming that greater rainfall variability is statistically associated with lower per capita GDP.

Kenya's Difficult Hydrologic Legacy: the Costs of Flood and Drought. In Kenya the costs of flood and drought are stark. The La Niña drought of 1998–2000, and the El Niño floods of 1997–98 each had devastating economy-wide and society-wide impacts, as illustrated in an analysis of the financial costs, off government accounts, of these events. The 1997–98 El Niño flood caused damages estimated at 11% percent of GDP (over 3 months). Over 90% of the calculated flood losses were associated with *transport* infrastructure damage (88%) and water supply and sanitation infrastructure damage (5%). The La Niña drought caused damage amounting to some 16% of GDP in each of 1998–99 and 1999–2000 financial years. It is interesting to note that the majority of these losses were associated with foregone *hydropower* (26%) and *industrial production* (58%). Agricultural losses associated with the drought accounted for 15% of drought damages, of which 10% were crop and 5% livestock losses. The remaining 6% of losses derived from adverse health impacts. The full economic costs in both cases are probably much greater, because these estimates did not include costs such as those from famine, hunger and malnutrition; losses of lives and rural livelihoods; and risk-averse behaviors such as relocation of industries or farmers' reluctance to invest in farm inputs such as fertilizers and pesticides. In a recent investment climate study[45], Kenya is shown to have very low competitiveness, with indirect costs for a firm about 3 times that of a strong performer. The largest share of the indirect costs is *transpor*t (31%) and *energy* (19%) – which are those sectors most affected by flood and drought. During 1998-2000, it is understood that major investors withdrew from Kenya due to unacceptable costs and risks.

Kenya: the impact of flood and drought

1997-8 El Nino Flood Impacts	**US$ millions**	%
Transport infrastructure	$777	88%
Water supply infrastructure	$45	5%
Health sector impacts	$56	6%
Total Flood Impacts	$878	
Flood Impacts as % of GDP 1997-8		11%

1998–2000 La Nina Drought Impacts	**US$ millions**	**%**
Hydropower losses	$640	26%
Industrial production losses	$1,400	58%
Agricultural production losses	$240	10%
Livestock losses	$137	6%
Total Drought Impacts	$2,417	
Drought Impacts as % of GDP 1998-2000		16%

Source: The World Bank (2004)

Source: Towards a Water-Secure Kenya: Water Resources Sector Memorandum, World Bank. 2004.

[43] There will be exceptions of course, in particular where major injections of external skill and capital have enabled water security to be achieved (e.g., Australia, the western United States).
[44] Brown and Lall (2006).
[45] Business Environment & Comparative Advantage in Africa: Evidence from ICA data. The World Bank, 2005

A 'transboundary' hydrologic legacy. The management and development of water bodies (rivers, lakes and aquifers) whose basins fall within the borders of more than one state are exceptionally difficult, due to the interplay of sovereignty and international relations. Reflecting this complexity, the UN Convention on the Law of the Non-Navigational Uses of International Watercourses was under preparation for 27 years prior to adoption by the UN General Assembly in 1997 and has not entered into force. Nevertheless, it is now widely agreed that the major principles within the Convention reflect customary international water law and these principles generally form the basis of negotiation of, and are being adopted within, regional, multilateral and bilateral agreements on international watercourses. The Rhine, shared by nine nations today, has long been an engine of Europe's economy, and has a complex institutional structure of demarcation and use evolved through over 500 treaties since the ninth century.[46] Nevertheless, there remain some inter-state tensions, such as a recent case between France and The Netherlands at the Permanent Court of Arbitration related to contamination from upstream mines in France. Colonial rule resulted in geographic divisions in the 20th Century that seriously compound the challenge of water management by cutting across watersheds and creating international rivers. In Africa, every country shares at least one international river with at least one other country(Guinea with 14, Mozambique 8); and virtually half of the international rivers in Africa (28 of 64) are shared by three or more riparian countries – the Nile basin has 10 riparians, the Niger basin 9.[47] The partition of South Asia in the middle of the 20th Century has also created great challenges. The need for robust international institutions is great, yet the international relations challenge for a poor nation to cooperate with even one state on one river is high. There can be many lost opportunities and increased costs, in terms of environmental costs to the river from poor management, economic costs of sub-optimal development of the river, costs from political tensions over the river, and costs of all the other opportunities foregone through non-cooperation.[48] The legacy of international rivers can very significantly affect the potential for managing and developing water to achieve growth and poverty alleviation.

Climate Change and Adaptation

Climate change will influence water security. The Intergovernmental Panel on Climate Change (IPCC) forecasts significant changes in precipitation, evaporation, cloudiness and temperature as well as increased climate variability in many areas as a result of global warming. Climate change will affect the demand for water. Irrigation – which accounts for some 80% of global water use – is the most climate-sensitive water user, and the shifting pattern of irrigated crops in response to climate change is likely to have major effects on the spatial

[46] Dombrowsky, 2001.
[47] Sadoff, Whittington and Grey, 2003.
[48] Sadoff and Grey, 2002.

and temporal pattern of water demand, as well as the need for increased water storage. Industrial and municipal demand will likewise be affected and further accentuated through the migration of people from increasingly water scarce regions to the water plentiful regions. Climate change will also affect the supply side of water resources management. Total global precipitation is likely to increase during the next century, although this increase will not be uniform across the world. Available water will likely reduce in Central Asia, the area around the Mediterranean, sub-Saharan Africa, and Australia in winter. It will likely increase in South Asia and South-East Asia during summer, and high latitude countries of the northern hemisphere in both summer and winter. Overall, global warming will likely lead to reduced water availability in the countries that are already water scarce and an increase in the variability with which the water is delivered.[49]

Hydrological variability and extremes are at the heart of the challenge of achieving basic water security. This challenge will be compounded by climate change, and everywhere it will require significant adaptation. [50] This will particularly be the case in poor countries which lack the institutions and infrastructure to manage, store and deliver their water resources, and where climate change will be superimposed on existing, and in some cases extreme, vulnerabilities. In many of the poorest countries, particularly in Sub-Saharan Africa, the currently unmanaged levels of climate variability are many times greater than predicted climate change. While many developed countries are focusing on mitigating climate change, developing countries are more focused on adaptation to current climate variability.[51] In all cases, however, adaptive capacity – both social and physical – will need to be enhanced to protect the poorest and most vulnerable populations.

Economic Structure and Resilience

The structure of an economy will also affect the nature and scale of institutions and infrastructure necessary for water security – with more vulnerable economies requiring more investment in water management. The economy's reliance on water resources for income generation and employment, and its vulnerability to water shocks will all be relevant. Water-vulnerable economies, for example those with highly variable rainfall that rely heavily on rainfed agriculture, or those whose most productive assets or areas lie in flood plains, will require more extensive investments in order to achieve basic water security. Not only will these

[49] Hirji and Ibrekk. 2001

[50] See Sperling (2003), "Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation," and inter-agency report by the AfDB, ADB, DFID, UK, BMZ, Germany, DGIS, The Netherlands, OECD, UNDP, UNEP, and the World Bank. Note also that significant debate continues regarding the impact of climate change on rainfall variability, droughts and floods.

[51] Such differing perspectives have been explored by Falkenmark (2000) "It could be that the developed countries are more likely to think of environment and security in terms of global environmental changes, and developing countries more with the human security implications of local and regional problems."

economies regularly suffer greater setbacks from water shocks, but this vulnerability will likely prove a strong disincentive for domestic or foreign entrepreneurial investments that could shift the structure of the economy toward a more diversified, water-resilient structure.[52] More diversified economies which are less water-dependent, and wealthier economies that can more easily compensate or insure those harmed by drought or flood, for example, might accept higher levels of hydrological uncertainty without slowing growth-focused investment. This suggests that efforts to guide structural change in the economy in order to achieve greater economic resilience to water shocks may have the potential to effectively act as an alternative to water investments by lowering the platform of infrastructure and institutions needed to achieve water security. There is also the potential for a virtuous circle phenomenon – where water investments produce gains that in turn are invested in diversified (less water-vulnerable) economic activities, and water security is reinforced.

The São Francisco River Basin and the changing structure of the economy in Northeast Brazil

Brazil, covering 8.5 million km^2 and with a population of 170 million (2004), boasts 14% of the world's fresh water resources. Yet while the country as a whole is relatively water-rich, the resource – like the population – is unevenly distributed. The semi-arid Northeast region, for example, is home to 30 % of the population, but possesses only 3 % of the nation's water resources. This region is the poorest in Brazil and is characterized by both water scarcity and rainfall variability – to the point where periodic droughts have in the past induced large migrations. The federal government determined that energy and water sustainability were essential for improving socioeconomic standards and increasing the economic viability of the region. Extensive multipurpose water infrastructure systems were therefore developed along the São Francisco River.

Several improvements in the northeast have been attributed to the development of the São Francisco River. Operation of the Sobradinho Reservoir has guaranteed flood control for cities downstream, reducing incoming peak flows and facilitating irrigation activities for an important fruit export center. Navigation and water supply to small localities has greatly improved the standard of living in the Sobradinho/Juazeiro-Petrolina stretch of the river. While Brazil is poor in fossil fuel resources, it is rich in water resources and 'head' (i.e. gradient). As a consequence, hydropower accounts for about 42% of the national energy matrix, and approximately 90% of the total electricity produced in the country. The hydropower infrastructure of the Northeast Region, particularly in the São Francisco River basin, has allowed economic growth similar to that of the rest of Brazil.

Development along the São Francisco River has also enabled the consolidation of important urban economies, including the metropolitan regions of Fortaleza, Recife, Salvador and other capitals of the Northeastern States. Moreover, economic changes have taken place in the production structure of the region, with noticeable growth in urban activities, such as industry and services, as opposed to agriculture and ranching. In addition to long-term benefits provided by this development, significant financial resources were captured by the local economy in the Sobradinho area during construction, encouraging development of existing municipalities and the establishment of new ones.

Source: "Hydraulic Infrastructure and Brazilian Development." Braga, 2005.

[52] Water (in)security will create incentives and disincentives for specific economic activities in particular geographic areas, which will influence both the structure of the economy and spatial patterns of growth, and hence impact overall growth and equity outcomes.

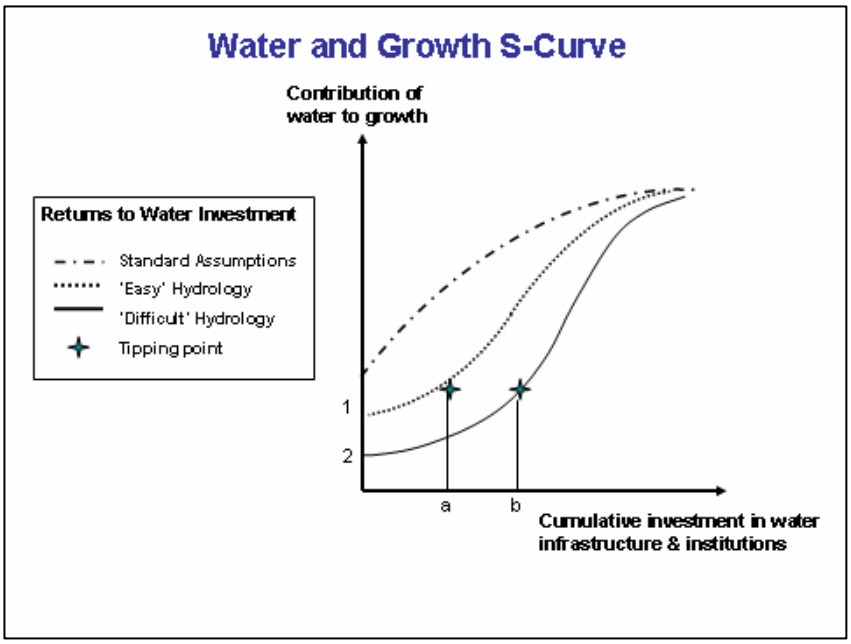
Risk Aversion

In the poorest countries, where survival is a real concern for large parts of the population and there are few functional social safety nets, economic actors tend to be extremely risk averse, investing only after there is significant demonstration of returns. Levels of risk aversion may therefore influence the threshold at which water security can be achieved and private investment follows. While the catastrophic effects of drought and flood extremes are clear, it is less well recognized that even in years of average precipitation, expectations of high variability and endemic droughts and floods may affect economic performance and, potentially, patterns of investment and the structure of the economy. In countries where hydrological variability is high and investments to achieve water security are inadequate, variability is a constant economic risk to small investors (such as individual farm families) and large ones (such as industries), and to the nation. The perception of risk is amplified by occasional droughts and floods. The expectation of variability and the unpredictability of rainfall and runoff are likely to constrain growth and diversification by encouraging risk-averse behavior at all levels of the economy in all years, as economic actors, particularly the poor, focus on minimizing their downside risks, rather than maximizing their potential gains. Individual farm families will quite rationally not invest in land improvements, advanced technologies or agricultural inputs, thus constraining agricultural output and productivity. Lack of such investments can lead to land degradation and desertification, which will result in a vicious cycle of reduced production and deteriorating assets. Similarly, there will be significant disincentives for investments in industry and services, which will slow the diversification of economic activities and maintain an economic structure that is based largely on low-input, low-technology agricultural production. The poorest countries may well face the highest risks, yet have the most risk-averse populations, the lowest infrastructure investment and the weakest institutions. This can be a very serious low-level equilibrium trap – as these countries must reach higher levels of institutions and investment, beginning from the lowest levels.

3.4 Dynamics of Water Insecurity and Security

The dynamics of water security can be illustrated in a hypothetical 'water and growth S-curve'. On the y-axis is a notional measure of the contribution of water to growth, which can be negative (destructive) or positive (productive). Along the x-axis is cumulative investment in water institutions and infrastructure (the appropriate mix of investment in institutions and infrastructure is discussed below.) The standard assumption would be that there is an initially high and then gradually declining return to growth from investments in water infrastructure and

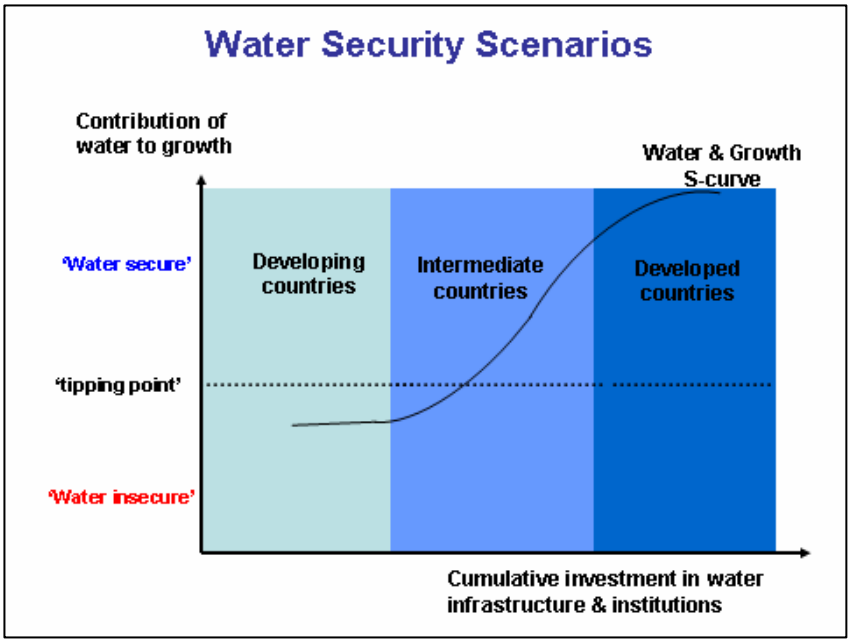
institutions. The S-curve illustrates an alternative hypothesis[53] that may reflect the reality of some – but not all – countries. Point 'a' marks the level of investment at which a country with 'easy' hydrology achieves water security, after which rapid growth is seen. Prior to this tipping point the returns to such investment are fairly modest. Point 'b' marks the level of investment at which a country with 'difficult' hydrology reaches water security. This is farther out along the x-axis, suggesting that countries with more difficult hydrology require greater upfront investments in infrastructure, institutions and capacity in order to achieve water security. The need for a larger minimum platform of investments could be a consequence of a more 'difficult' hydrology (flood risk, or more international rivers, etc.), a more water-vulnerable economy, or a more risk averse population – all of which puts the country in a "deeper hole" as it tries to mitigate that variability and achieve a basic level of water security.



Many other factors will also influence this dynamic. For example, a higher level of investment may be needed for institutional reform if governance or capacity are particularly weak in a given country. The political economy of institutional reforms will also affect the dynamic of this hypothetical curve, shifting the "S" outward with increased resistance to reform. On a more positive note, better technologies and more efficient management policies (i.e., demand management and pricing) may lessen the need for investment, either shifting the "S" inward or achieving a concave curve which is generally assumed with early investments.

[53] This is an untested hypothesis for discussion, for which there is some strong anecdotal evidence.

The 'S-Curve' can also be used to illustrate the differences in water security scenarios. Developing countries will generally be along the lower, water-insecure or water-vulnerable horizontal segment of a 'difficult' hydrology S-curve. Intermediate economies are often along the steep, tipping point segment, and developed economies are generally along the upper, water-secure horizontal segment.



Implications for Investment and Economic Analysis

It is worth noting that the 'S-curve' is constructed to indicate that early incremental returns to investment in water resources, in some circumstances and perhaps particularly in countries with high hydrological variability, may appear to be fairly low. It is posited that a significant public investment may need to be made before there is basic water security (e.g., sufficient storage to regulate flows) for private investment to follow and growth unconstrained by water to ensue – much like a road investment which will have little return until it joins two cities. If this is in fact the case, it has important implications for the way in which we assess the cost-effectiveness of early investments in water resources infrastructure. Standard tools of project economic analysis may be problematic for many reasons: they focus sharply on marginal rates of return which may be misleading if applied to large inter-related, multipurpose water infrastructure systems; and they assess only direct costs and benefits without capturing forward linkages and multipliers[54] and the impact of basic water security on private sector investment responses.

[54] Bhatia, Scatasta, Cestti and Malik (2005).

Such tools are generally inadequate to capture the potentially transformational impacts of large-scale, multipurpose investments.[55] These impacts can be economic, social and environmental – and both positive and negative.

This is not a new dilemma. Hirschman in the 1950s[56] described both the critical importance of social overhead capital (roads and power), and the challenge of imposing economic discipline in planning such investments. He wrote "The trouble with investment in [social overhead capital] … is that it is impervious to the investment criteria that have been devised to introduce some rationality into development plans." Economic tools have evolved significantly since the 1950s as practitioners have gained a broader understanding of the impacts (economic, environmental and social) and values (both use and non-use) associated with water development, and economists have refined methodologies to capture them. There is an iterative, dynamic process of better understanding and better modeling the positive and negative impacts of water development.

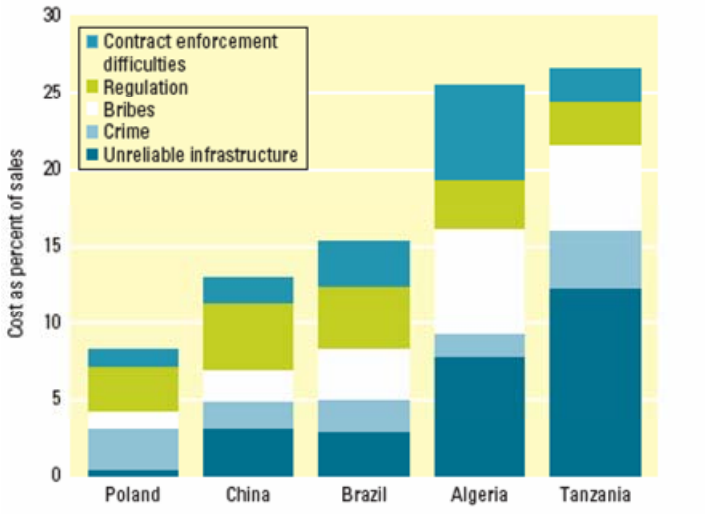
3.5 Financing Basic Water Security

Early investments in water security have historically been considered classical examples of public goods, overwhelmingly financed by public investment from fiscal resources. In Wealth of Nations, Adam Smith wrote that government should construct public works when these works are "of such a nature, that the profit could never repay the expense of any individual or small number of individuals, and which it therefore cannot be expected that any individual or small number of individuals should erect or maintain." Hirschman[57] made similar arguments noting that "Investment in social overhead capital is advocated not because of its direct effect on final output, but because it permits and in fact invites directly productive activities to come in."

Following similar logic, when basic water security is achieved and additional investments in water or water using activities can be highly profitable (i.e., in agriculture or power), one would expect to see increasing private investment responses throughout the economy.[58] All rich countries have achieved basic water security through public service provision, and have done so primarily through public finance with a judicious mix of private financing. The cost of providing infrastructure to such large un-served populations in developing

[55] A potentially quite important area for research in this regard would be an exploration of the way in which evaluation methodologies have generally followed rather than led development, and the dangers of adapting methodologies out of context. Reuss (2003), for example, characterizes current water resources planning in the U.S. as "planning by constraints" related to environmental and social imperatives, a formulation that may be appropriate for the U.S. with its highly developed infrastructure stock, but may be inappropriate for the poorest countries where basic needs, flood and drought infrastructure is not in place.
[56] Hirschman (1958.)
[57] Ibid.
[58] While this is just one of many factors that influence private investment, it is generally seen to be quite significant.

countries – while meeting global standards of sustainability and equity as well as maintaining adequate maintenance of the infrastructure stock and prudent fiscal management – is truly daunting. Meeting this challenge will not only take innovations in water resource management, development and governance, but also in financing. Changes may be called for in the way that the international community supports and prioritizes water investments, and public-private partnerships options should continue to be explored. All investment, whether public or private, should be complemented by robust regulatory and monitoring frameworks, designed with the active participation of water users and civil society.



High costs to the private sector from unreliable infrastructure and governance

Source: World Development Report (2005).

4. The Dynamics of Institutions, Infrastructure and Values

4.1 Institutions and Infrastructure

Throughout this paper, we have written of water institutions and infrastructure, because in all countries development of water resources will require investments in both. What is the balance and sequencing between them? All human society has sought to manage and develop water to the extent necessary to sustain lives and livelihoods. From village wells and ponds, to canal systems, to earth bunds in the flood plains of great rivers, all have been developed for millennia and each

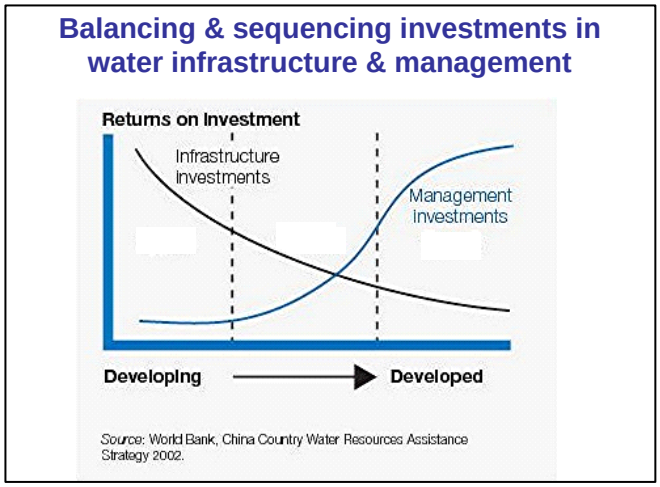
has been accompanied by evolution and adaptation of institutional systems necessary to plan, develop, manage and maintain such infrastructure. In some cases, these institutions were an early form both of government – an emerging 'public sector' to manage public goods, as well as of business – an emerging 'private sector' providing services to meet public demand. Water institutions themselves will reflect the culture and political economy within which they fit: public to private; centralized and hierarchical to decentralized and participatory; rules-based to market-based.

An important observation, however, is that over the past century or so there has been a change in this balanced relationship between water development and water management, due to an explosion in the development and worldwide adoption of new technologies and engineering capabilities. The institutions needed to manage these advances, however, have often been slow to adapt. The case of groundwater is illustrative, where the cultural practice and customary law of groundwater development was well-adapted to technologies which did not allow substantial groundwater abstraction from any but very shallow depths. With the introduction of motorized drilling rigs and pumps, allowing higher pumping rates from greater depths, a groundwater development revolution has taken place. Yet groundwater management policies and practices have not adapted in many countries, resulting in massive groundwater over-abstraction with serious and sometimes irreversible consequences.

4.2 Balance and Sequencing

At all times, concomitant investments must be made in infrastructure and institutions, but when stocks of hydraulic infrastructure are low, investment in (man-made and natural) infrastructure may provide relatively higher returns. Investment in management capacity, and infrastructure operations and institutions may become increasingly important as larger and more sophisticated infrastructure stocks are built – as illustrated in the hypothetical diagram below. In most developed countries significant infrastructure investments have been made (in some cases arguably excessive investments) and much greater returns are now derived from improving water resources management and infrastructure operations. In some of the world's poorest countries, infrastructure stocks may be so low that investments in management might not have the same high returns. Without the infrastructure to store and deliver water and manage flows, water managers and institutions, no matter how sophisticated, are severely constrained. This suggests that while developed countries with ample infrastructure stocks are appropriately focused on the implementation of water management and infrastructure operations, there may be some developing countries in which it is more appropriate to place a relatively greater emphasis on infrastructure investments – just as developed countries did at a similar point in their development, but with the added advantage of drawing on global good practice to do so. As these infrastructure investments grow, it is imperative to ensure a

balance with investments in institutions and capacity building, recognizing that institutional development and reform can be slow and difficult.



Failure to understand the issue of balance and sequencing of infrastructure and institutions within the context of specific country circumstances may lead to poor investment choices. One potential danger is that most donor nations are strongly focused on water management as a priority, when in fact water management will provide little return when there is insufficient infrastructure with which to manage water, and the priority of the client countries may well be for investment in this infrastructure. It is important that donor perspectives do not obscure the priorities of developing countries, and, at the same time, it is important that developing countries ensure the development and adaptation of water management institutions in parallel with their infrastructure investments.

4.3 The Transboundary Challenge

The case of international rivers is of growing importance in a world of 260 such rivers, shared by about 90% of the world's nations. While a basic premise of water resources management is that river basins are best managed and developed as an integrated whole, this is always legally and politically complex due to the challenges of allocation between users and between uses. The management and development of international rivers is particularly challenging, due to the fact that there is no apex authority through which differences can be resolved and, although criteria for allocating water and the benefits of water can be drawn from a growing body of customary international water law, there is no consensus on the criteria for equitable allocation.[59] Nations often seek to develop river segments within their own territories, settling for second or third best

[59] Sadoff, Whittington and Grey, 2003.

investments from an unconstrained basin-wide perspective, as the complexity (and associated cost) of riparian relations is an obstacle to the development of the full potential that international rivers embody for growth and poverty alleviation. In extreme cases, tensions over international rivers can effectively halt their management and development. Developed economies have in most cases achieved a relative equilibrium in establishing fit-for-purpose transboundary institutional arrangements, including treaty regimes dealing with issues of river infrastructure and the quantity and quality of water flows. In many cases, the need for river infrastructure, such as locks for navigation or weirs and dykes for flood management (e.g., the Rhine) or hydropower facilities (e.g. the Columbia River), were primary drivers for adopting institutional solutions. In the second half of the 20th Century, with water quality a growing concern, there has been an increasing emphasis on joint institutional solutions to restore riverine and lacustrine ecosystems (e.g., the Rhine and the Danube).[60] Increasingly, cooperative efforts are focusing on the sharing of benefits, rather than water. Where water allocations are generally perceived as zero-sum negotiations, cooperative management provides opportunities to increase the scope and scale of benefits from international rivers – benefits that can then be shared by mutual agreement.[61] The shared benefits of cooperative management (say for flood management and mitigation, or for water quality) and development (say for irrigation and power) can provide the incentives to establish and sustain transboundary institutions.

Sharing benefits: the case of the Nile Basin Initiative.

The riparian states of the Nile Basin launched the Nile Basin Initiative (NBI) in 1999, reversing long-standing predictions that conflict was inevitable over the resources of the Nile, the world's longest river, linking 10 African countries, 5 of them among the 10 poorest countries in the world. Instead, the riparian states are telling their people and the world that if they work together to manage and develop their shared water resources, substantial benefits – more water, more food, more power, less flood and drought – can be derived and that these benefits can be equitably shared. The NBI has launched a suite of basin-wide projects to build trust and capacity, to lay the foundations for joint development. Following this, the NBI is now identifying major joint investment projects in irrigation, power generation and trade, river basin and watershed management and flood mitigation, bringing tangible benefits to the people of the basin. Despite the inherent difficulties of multi-country cooperation, serious efforts are being made to identify optimal solutions – with regional assessments 'removing borders' to identify best options, to identify benefit sharing mechanisms, and to ensure good social and environmental practice. The waters of the Nile are strictly limited, but the benefits from cooperation are much less so, as they could extend far beyond the river itself, lifting barriers to trade and investment and broader economic integration. The Nile Basin Initiative is an important example of how, with courage and vision, transboundary waters can be turned from a barrier to growth to an opportunity for growth.

[60] This trend is clearly demonstrated in Lautze and Girodano (forthcoming).

[61] Benefit sharing also provides riparians with the flexibility to separate the physical distribution of river development (where activities are undertaken), from the economic distribution of benefits (who receives the benefits of those activities.) This allows riparians to focus firstly on generating basin-wide benefits (a positive-sum exercise), and secondly on sharing those benefits in a manner that is agreed as fair. See Sadoff and Grey, 2005

4.4 Changing Priorities, Changing Objectives

As countries grow and the welfare and dignity of their populations become more secure, their relative values and priorities often change. This may be especially true for water resources management (institutions) and development (infrastructure). Writing in 1946, Ghandi believed that all India's rains should be stored so that famine could be overcome.[62] Writing in 2003, Martin Reuss of the U.S. Army Corp of Engineers describes the trend in water resources planning objectives in the USA as increasingly setting limits to growth by placing high value on non-human needs.[63] Evolving societal values and economic growth in Canada have led BC Hydro to re-engineer its hydropower structures, placing high value on improved in-stream flows and fisheries, at some (although not great) cost to hydropower production.[64] A downstream nation on the Rhine at great risk from flooding from the river as well as from inundation by the sea, the Dutch have struggled to shift from control of society by the river, to control of the river by society, to, more recently, a strategy that makes "room for rivers" by finding a more adaptive balance between the river and society.

In many industrial countries, often following periods of significant economic growth, there tends to be a great deal of emphasis on re-operation or re-engineering of existing infrastructure systems to optimize performance and to meet evolving environmental and social priorities. Many developing countries, on the other hand, find their infrastructure stocks to be inadequate and therefore see an overarching imperative to invest in new water infrastructure in an attempt to reduce the destructive costs and increase the productive value of water in their economies.[65] The social and economic cost of not developing water, of simply maintaining the status quo, may also be much higher in developing economies where many people are physically vulnerable and live in life-threatening poverty.

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[62] 'In this land of ours, fabulously rich in natural resources, there is the lofty Himalayas with its ever-lasting snows where, they say, dwells the Lord of the Universe. It has mighty rivers like the Ganges. But owing to our neglect and folly, the year's rains are allowed to run down into the Bay of Bengal and Arabian Sea. If all this water was trapped and harnessed for agriculture purposes by the construction of dams and tanks, there should be no famine or food shortages in India.' Mahatma Gandhi, 1946.

[63] "Replacing both the scientific efficiency model of the early twentieth century and the more recent economic efficiency model is an approach that I can characterize only as planning by constraints. The process emphasizes regulation and focuses on water quality, rather than quantity, issues. Rather than maximizing economic efficiency or optimizing the opportunity to meet public objectives, it sets limits to growth. To what extent it remains basically an anthropocentric process, in which sustainable development is justified economically as well as morally, or reverts to a biocentric ethic which grants to other living things a moral worth equal to that of the human population, is a great question. Certainly, any process that grants inherent moral worth to nonhumans establishes a system of competing claims that ultimately sets limits on human population, patterns of consumption, and technological development. Any equitable solution to these problems of competing claims with nonhumans would require the application of a system of ethics and a notion of justice that substantially modifies the value system of western civilization." In: "Federal Water Resources Planning" by Martin Reuss, Office of History, U.S. Army Corps of Engineers. (2003)

[64] Daryl Fields, personal communication.

[65] During World Water Week 2005: "Many high-level public officials emphasised during the week that investments in hydraulic infrastructure are a basic necessity for economic growth in many developing countries. Infrastructure helps in coping with rainfall variability and climate change and in achieving long-term water security." See SIWI (2005).

There is thus a clear willingness in many developing countries to face the trade-offs required to further these goals, mitigating their inevitable costs by the pragmatic application of social and environmental safeguards. As economies grow, these trade-offs may become less stark – both because economic security lowers the cost of inaction, and because mature infrastructure systems offer greater scope for re-engineering and re-operations that will meet evolving, multiple objectives with less social and environmental disruption.

4.5 Alternative Development Paths

This path of shifting values is obvious, yet commonly unrecognized. In an increasingly globalizing world, there are pressures on developing country institutions to adopt developed country priorities and standards. Within this dynamic, however, the immediate and often extreme growth and poverty challenges faced by developing countries may not be fully acknowledged. At the same time, developing countries may not fully appreciate how greatly their values and priorities are likely to shift with growth, and therefore do not recognize this in their planning. Hydraulic infrastructure is characterized by its longevity and by its broad impact on the environments and societies in which it is built. Hamilton and Johnson[66] point out that much of the infrastructure built in the next 20 years will still be with us in 2050, and that some choices are irreversible or can be reversed only with great difficulty. In virtually all developing countries, demand for water, food and power continues to grow and there is no question that hydraulic infrastructure is needed.

Herein lies the challenge. Can the lessons of developed countries, enhanced by local and indigenous knowledge, provide insights into alternative management strategies and infrastructure designs and operations – or alternatives to infrastructure altogether – that still achieve water security, growth and poverty alleviation but have lower environmental and social impacts? Scale, site selection and operational characteristics need to be assessed from a long-term planning perspective, incorporating anticipated trends and emphasizing adaptability. This will ensure that future generations inherit institutions and infrastructure that can readily adapt to their evolving values. While no radical alternatives present themselves to the difficult task of managing and developing water resources through an evolving balance of institutions and infrastructure, there has been a steady process of learning and innovation that provides numerous lessons for following this basic path in a more sustainable and balanced way. There is a growing body of analysis, literature and tools that can assist, such as the recommendations of the World Commission on Dams and the International Hydropower Association, and the environmental and social safeguards of the World Bank.

[66] Hamilton and Johnson (2004).

Focusing on Resource Management

A great deal of progress has been made in water resource management, with a broad global consensus on the principles, forged during the Rio Earth Summit (1992) and reflecting the 'Dublin Principles."[67] Good practice requires institutions to promote equity, efficiency, participatory decision-making, sustainability and accountability.[68] Engineering, technological and scientific advancements have broadened the range of investment design and adaptive management options available. Important evolving practices include innovations in environmental and social impact analyses (particularly of local project-affected populations and environments), in-stream flow management, environmental set-asides, demand management, re-engineering and re-operations, enhancement of natural water storage and regulation, and benefit sharing with affected populations and even international partners. Tools such as participatory multi-criteria analysis, monitoring, review and consultation mechanisms are informing investment decisions, leading to better design and stronger implementation. Mechanisms such as water rights, allocation, pricing, wastewater fees and regulations are increasingly being used to ensure better management of both the quantity and quality of the resource.

Focusing on Society

Balancing the aspirations of society at large with protection of individuals in water resource management and development decisions, is an enduring challenge that plays out in the context of the larger socio-political arena. Great emphasis is being placed on understanding and supporting the challenges of affected groups, disenfranchised peoples and women. Strategies and tools are continuously evolving for more effective social and gender impact analyses and safeguards, successful development communications, broader inclusion, greater transparency and more equitable benefit sharing. Stakeholder involvement, information sharing and constructive communications are key.

Focusing on Economic Resilience

In addition to improving management of the resource, there may be potential for managing the economy to make it less vulnerable and more resilient to water

[67] The Dublin principles were adopted at the International Conference on Water and the Environment (ICWE) in Dublin, Ireland in January 1992. They are as follows: Principle No. 1 - Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Principle No. 2 - Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels. Principle No. 3 - Women play a central part in the provision, management and safeguarding of water. Principle No. 4 - Water has an economic value in all its competing uses and should be recognized as an economic good.

[68] These are the five core values defined by the World Commission on Dams.

shortages and shocks. Increased investments in more water-resilient sectors, settlement and production in areas with less water stress or climate variability, trade in virtual water, and greater economic diversification more generally could all diminish an economy's vulnerability to water shortages and shocks, and potentially lessen the need for water development.

5. Wealth, Poverty and the Burden of Proof

5.1 Water, Poverty and Wealth

These observations have real implications for development priorities and appropriate levels and mixes of investment in water resources, for program design, project economic analysis, and the potentials and constraints for developing countries to "leapfrog" their water institutions and infrastructure while avoiding the mistakes of the past. It suggests that we would expect to see a world where societies are poor where water is scarce or in excess, and/or water availability is highly seasonal and/or variable, because basic water security has not been achieved and a minimum platform is not in place. There will be exceptions, in particular where major injections of external skill and capital have enabled water security to be achieved (e.g., Australia, the western United States.)[69] On the other hand, we can expect to see a world where societies are relatively rich where water is sufficient, widespread and reliable and water security was easily achieved – mostly in temperate climates with low rainfall seasonality/variability. There will of course be other reasons why societies are poor or rich, but we postulate that the significance of water investment is considerable – and little recognized.

5.2 Water, Growth and Aid

This lack of recognition of the significance of water investment has serious consequences for poor countries. The focus of industrial countries is correctly on water *management* and *operations*, not on water *development*, because existing infrastructure stocks are adequate. In the case of the U.S., after trillions of dollars have been spent on hydraulic infrastructure investment, some $21 billion per year will be spent over the next ten years to reach US environmental standards.[70] Clearly, the priority focus of the most developed countries can differ from those of the least developed. In industrial countries, a focus on water management and operations, and away from water development, is reflected in the substance of university training, research, consultancy services, and industrial production. It has also permeated through to aid policy. This focus, combined with the

[69] See earlier discussions on the costs of achieving this water security and the ongoing challenge of sustainability.
[70] Jerome Delli Priscolli, USACE, personal communication.

controversy that often attends infrastructure investments, leaves little appetite among aid policy makers for supporting major water resources infrastructure development in poor countries and tackling the unavoidable tradeoffs that this entails. Opposition, particularly to the financing of dams for storage, hydropower or other purposes, is strongly advocated by many (often western) lobby groups, some of which have access to substantial financial support and can therefore have significant political impact on the aid policies of donor governments and international organizations.

Yet there is very little discussion of the growth and poverty implications of diminished support for water infrastructure in poor countries – in particular of the costs of inaction – and of the moral hazard this entails for donor countries. The debate would benefit greatly from a better understanding of how developed countries have dealt with hydrological vulnerability, and how they have used strategic investments in water infrastructure to reduce risk, alleviate poverty and catalyze growth. The inevitable trade-offs involved in water development cannot be thoroughly assessed without an examination of the potential benefits of growth and poverty alleviation that can be derived from well-designed and well-managed water infrastructure. The lessons learned from these experiences will help inform discussions of feasible alternative paths for water development that maximize benefits while minimizing environmental and social disruption, and safeguarding the interests of project-affected communities in particular.

At the same time, poor countries must not see infrastructure alone as a panacea. Without the development of appropriate water institutions, badly-managed infrastructure will likely not support growth, it (and its associated debt) may even forestall growth. The world is a different place in the 21st Century, and there is no doubt that the costly mistakes of the past can and must be avoided in the future. Water infrastructure, though essential, can and must be developed in parallel with sound institutions and with great attention to the environment and to equitable sharing of benefits and costs. And it can and must be robust and flexible, designed to allow its operation to adapt to changing values and priorities. Only then can water investment support responsible growth.

Unless these dynamics are recognized – by finance and planning decision makers in developing countries and by policy makers and aid administrators in developed countries – it will be extremely difficult for water security to be sustainably achieved in the world's poorest countries, severely constraining growth.

5.3 The Burden of Proof

Almost all developed countries have followed a broadly similar path of early and extensive investment in water resources institutions and infrastructure to achieve water security and underpin growth. Today, most wealthy countries invest almost

exclusively in improving water system operations and in institutional strengthening. Developing countries expect to have to follow the same path to water security and growth, and to have the support of developed countries as they do so. If this is not the case, and poor countries will not have the help of developed countries to invest in water resources infrastructure to achieve water security, but instead are asked to follow an alternative and arguably more benign development path, then where does the burden of proof rest that there is another path which is both affordable and demonstrated at scale? The 4th World Water Forum is an excellent opportunity to openly explore alternatives for more responsible growth, and further this important discussion.

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