Changing Global Water Management Landscape

Asit K. Biswas and Cecilia Tortajada

Change is the law of life. And those who look only to the past or present are certain to miss the future.

John F. Kennedy

Introduction

In the sixteenth century, the eminent Renaissance scholar Leonardo Da Vinci said that water is the driver of nature. During his lifetime, some may have considered this to be an overstatement, but some half a millennium later, Leonardo's understanding of the role, relevance and importance of water to society and nature can be considered to have been prophetic. Water is increasingly considered to be the lifeblood of the planet and, at present, it will certainly not be an overstatement to claim that without efficient water management, the future social and economic development of the world would be seriously constrained, or even significantly jeopardised. Both developed and developing countries will require implementation of more and more efficient water management policies and practices in terms of both quantity and quality. However, developing countries will need to improve their water management practices and processes much more than developed countries, especially as the current practices of the former have significant potential for improvement.

As the human population has grown, the global food requirements have increased as well and with it the requirement to water needed to produce the necessary food. At present, most of the global water use is accounted for by the agricultural sector, estimated at about 70%. Historically, water–food interrelationships have always been important. However, in recent years, these linkages have become more and more complex because of national and international politics, social and environmental considerations, different forms and levels of subsidies and tariffs applied to food products in different countries, globalisation, free trade, changing standards of living, institutional and legal requirements, technological developments and management practices.

A.K. Biswas (✉)
Third World Centre for Water Management, Av. Manantial Oriente 27, Los Clubes, Atizapán, Estado de México, 52958, Mexico
e-mail: akbiswas@thirdworldcentre.org

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In percentage terms, agricultural water use worldwide has been declining in recent decades (in absolute terms it is still increasing). However, industrial water use has been steadily increasing since the advent of the Industrial Revolution, when global development patterns changed dramatically. Industrial water requirements started to increase rapidly, as did the need for collection, treatment and environmentally safe disposal of wastewater generated. As the nations industrialised, their industrial water requirements increased as well. Accordingly, in all the industrialised countries, industrial water demands have long exceeded domestic water needs. Similarly, as developing countries become industrialised, their water requirements for this sector have increased as well. Accordingly, industrial water needs in many developing countries at present are already higher than their domestic water requirements, and this trend is likely to accelerate in the future.

With rapid industrialisation, improving standards of living and consistent demands for a better quality of life, energy requirements of nations have gone up as well. For example, in recent years, electricity requirements of many developing countries like Brazil, China, India, the Philippines, South Africa, Thailand and Turkey have been increasing at more than 5% per year. Since these demands are increasing from a historically low base, they will continue to rise at a high rate during the coming decades. This comparatively recent development has had major water-related implications, since no large-scale generation of electricity can be achieved without water. Water, of course, is essential for hydropower generation. Equally, thermal and nuclear power cannot be generated without the availability of large quantities of cooling water. In turn, the water sector is a major user of energy, especially in terms of pumping. These symbiotic interrelationships between the water and energy sectors, for the most part, have been ignored by the water and energy professionals in nearly all the countries of the world.

Environmental and social implications of development projects started to become important during the 1970s. They gathered further momentum during the 1980s and 1990s, by which time environmental impact assessments of all major projects had become mandatory in most countries. During the past three decades, many lessons have been learnt as to how major development projects can be planned, constructed and managed so that the overall results are economically efficient, socially acceptable and environmentally friendly. Water development projects have been no exception to this comparatively new but essential requirement, also working towards the generation of new knowledge for better planning and management practices.

All the above-mentioned and many other associated developments have ensured that, over the past five to six decades, water planning and management have become an increasingly complex and difficult task all over the world. Many of the current and emerging trends indicate that this process will become even more complex in the coming years, most likely at a more accelerated rate than has been witnessed during the recent historical past. Because of these accelerated complexities that should be realistically expected in the future, many of which are likely to stem from non-water sectors on which water professionals are likely to have a limited say or control, it is essential that water planners and managers should start thinking seriously about the trends and developments in the post-2020 world. Changes in many water-related areas are likely to be so fast in the future that past experiences and present practices may at best be of limited use to manage them in an efficient and timely manner.

Planning and construction of large water development projects often span more than two decades. This means that many new generations of water projects that are being planned now may become fully operational around 2030, or even later, when the overall environment and the boundary conditions within which they will be operating are likely to be very different from what exist at present. Thus, it is essential that the water professionals start taking a futuristic look so that the major planning assumptions of current projects are still likely to be valid in a post-2030 world, when they are likely to become operational. Regrettably, this is an aspect that is being mostly ignored at present.

While it will be a very difficult task to predict the future changes that will affect water management in a post-2020 world with any degree of certainty in terms of their spatial and temporal nature, their magnitudes or even the timing of the onset of any specific change, one aspect can be predicted with complete certainty: that is that major changes will occur which will require development of new paradigms for water management, including new and innovative approaches for water planning. Yesterday's experience and today's approaches are likely to be of limited value in understanding or identifying tomorrow's trends, let alone solving the day after tomorrow's water problems. For water managers, business unusual has to be the new *mantra* of the day.

Future Drivers of Change

During the next two to three decades, there will be many drivers of change which will affect water availability and use patterns. These driving forces can be classified into three general categories. First, some of these drivers are well known since they have affected water management practices and processes in many ways in the past. However, even for these drivers, like population and urbanisation, their potential implications in the future are likely to be somewhat different than have been witnessed in the past. Linear extrapolation of past trends will give a misleading development scenario for the future. Hence, even for this group of drivers, considerable thinking and further research will be needed to predict reliably their future water-related implications and how these can be efficiently incorporated into water management processes.

There are other drivers, like economic growth and energy generation, which constitute the second category that will affect patterns of water use and consumption, as well as wastewater generation. While the relevance of these factors has sometimes been implicitly recognised in water management, they have seldom been explicitly considered for policy and planning purposes.

The third category of drivers is those which, for the most part, are being completely ignored by mainstream water professionals at present. Among these drivers are issues like globalisation, free trade, immigration, advances in biotechnology and desalination, diseases like HIV/AIDS, changing management paradigms and evolving social attitudes and perceptions.

Only some of the above-mentioned drivers will be discussed in this introductory chapter, primarily to give an indication as to how these issues are likely to affect water management in the future, directly or indirectly. Many of these drivers have been discussed in more detail by other authors in this book. It should be noted that the changing patterns of these drivers and their potential implications to the water sector are still not fully understood and thus, not surprisingly, even less appreciated by water professionals at present. In fact, a good research agenda in this overall area is currently conspicuous by its absence. Equally, the impacts and the relevance of these drivers may vary from one country to another and may even vary within any specific country, as well as over time.

Economic Growth and Water

It has been anecdotally known for at least half a century that economic growth affects water consumption patterns through a variety of pathways, which can be direct, indirect or tertiary. Some of these changes are predictable and quantifiable and thus comparatively easy to handle within the existing management process. However, many other changes are unknown, unpredictable and/or intangible, as a result of which it has been very difficult to incorporate them explicitly in terms of overall planning. Equally, water resources, if planned and managed properly, can act as an engine for promoting regional economic growth and for alleviating poverty. Comprehensive analyses carried out by the Third World Centre for Water Management clearly indicate that projects like Bhakra Nangal in India (Rangachari, 2006), High Aswan Dam in Egypt (Biswas and Tortajada, 2009) and Ataturk Dam in Turkey (Tortajada, 2004) have radically transformed the economic growth patterns of the regions concerned by generating new employments, enhancing energy and food security conditions and improving major social indicators.

The last 20 years have seen radical changes in the economic growth patterns of several developing countries. The recession of 2008 and its expected continuation in 2009 will undoubtedly affect the earlier forecasts of economic growths in all parts of the world, but the relative patterns of economic developments are unlikely to change significantly from what were estimated earlier, especially over the medium term. All these changing economic growth patterns will, in turn, have a myriad of implications in terms of water planning and management through a series of interacting pathways and feedback loops. These interacting patterns are still not fully understood, but they would invariably have noteworthy implications for both water quantity and quality management in the future.

The countries having some of the highest prospects for economic growth in the coming years are Brazil, Russia, India and China, collectively known as BRICs, a term that was first coined by Goldman Sachs. The aggregate contribution of BRICs to global growth has been around 30% since 2000 and exceeded that of the United States by the end of 2008. China has already become the world's fourth largest economy and is expected to surpass Germany by around 2010. The GDP of China has more than doubled since 2000, meaning that it has effectively created a contribution that is equivalent to an additional France, two Canadas or three Indias. In the case of India, the increase in terms of its GDP is equivalent to that of the Netherlands in 2000 (Goldman Sachs, 2006a).

Globally, the pace of economic growth is expected to slow between 2008 and 2010. However, long-term high-growth projections pose potential major challenges to the environment by placing additional pressure on natural resources utilisation. In the case of water, these economic growth rates will have major implications in terms of access, quantity, quality, equity and management and investment requirements. These developments will pose major challenges in the future because current policy measures will not be able to address these emerging developments adequately or systematically. Unless a determined effort is made to change the current approaches properly, current and future water policy measures are unlikely to address the expected changes adequately. There are no signs at present that innovative and appropriate sets of water policy measures can be formulated and implemented in a timely manner in countries that are likely to have high economic growth rates.

The type of economic growth that can help preserve the environment, and decrease pollution, water included, should also improve the living conditions of the average citizen significantly. The growth should improve income distributions within the countries as well as between the countries. Nevertheless, even in a scenario of robust economic growth, increased income and improved environmental quality are not always related since more affluent countries and better-off citizens do not automatically protect the environment. At least for the OECD countries, in general, pollution levels have decreased, and the interest in preserving the environment has increased in response to domestic demands that can be supported by sound investment and public policy initiatives (OECD, 2007).

Since developing countries started from a lower base, Goldman Sachs (2006b) has estimated that three conglomerates of countries (G6[1], BRICs and N11[2]) would together need, over the next 5 years, total investments of approximately $4 trillion for infrastructural developments. Almost half of this requirement is likely to be accounted for by the BRICs. Even if the above-estimated amounts are actually invested, it would still take the BRICs another 25 years to have a level of infrastructure equivalent to that of the G6 countries at present.

In order for the above-mentioned countries to achieve real growth, Goldman Sachs (2006b) identified certain priority issues which have to be considered, such as savings, population growths and productivity gains. They also identified issues such as good governance, sensible policies, strong institutions and appropriate legal and regulatory frameworks to encourage the participation of the private sector. All countries should consider these as priority issues irrespective of their stages of development or the development sectors concerned.

Goldman Sachs has estimated that commitment from the private sector to energy, telecommunications, transport and water in all developing countries over the past

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[1] G6 consists of United States, Japan, Germany, Italy, United Kingdom and France.

[2] N11 consist of Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey and Vietnam.

15 years has been approximately $60 billion per year. In the short term, telecommunications (mostly mobiles) may receive 50% of the total global private investments, while electricity generation, roads and water projects may receive 35, 15 and 5%, respectively. Over time, investments are expected to be channelled to electricity generation and roads, although this will depend on the policy frameworks of the different countries and their attractiveness to the private sector (Goldman Sachs, 2006b).

An interesting aspect that should be noted is that, during the second half of the 1990s, there was optimism that water supply and wastewater management problems of the urban developing world would be solved by the private sector, which would bring with it additional investment funds and good management expertise that the public sector did not have. After some early promise, the multinational companies have basically lost much of their initial enthusiasm to invest in the water sector during the post-2000 period. Thus, an important aspect of any future private sector involvement in the water sector has to be the separation of the short-term blips from the long-term trends.

Population

Historically, population has been an important driver for the water sector. As the global population increases, unless the existing water management practices become more and more efficient, the world will require significant additional quantities of water to sustain its inhabitants at a reasonable standard of living. However, unlike oil or coal, water is a renewable resource. This means that water can be used, and then reused, many times as long as proper water quality management practices are followed. Thus, water poses a very different type of management approach compared to nonrenewable resources like oil or coal.

In terms of water management, population has many other implications, in addition to just numbers. Among these are concentration (urban or rural), age structure and gender-related issues.

Historically, the world population has increased steadily. However, the growth rates have regularly varied with time. In 1950, the global population was estimated at 2.53 billion (Table 1). By 2000, it had more than doubled to 6.12 billion (an increase of 1.42 times). By 2050, half a century later, it is estimated to increase to 9.19 billion. This indicates an estimated increase of around 50%, which is only about one-third of the growth that was witnessed during the previous 50-year period.

The decline in the global population growth rates has been quite significant in the recent past. For example, during 1970–1975, the growth rate was 2.02% per year. This is expected to decline by 82% during the 2045–2050 period, to about 0.36%.

While the world population will increase steadily up to 2050, its distribution over the different regions will not be homogenous. While Asia's share during the 1950–2050 period will remain fairly similar in percentage terms, Africa's share will increase from 8.8 to 21.7%. In contrast, Europe's share will decline from 21.6% to 7.2% (Table 2).

Table 1 Total population (thousands), 1950–2050

Year	Total population
1950	2,535,093
1960	3,031,931
1970	3,698,676
1980	4,451,470
1990	5,294,879
2000	6,124,123
2010	6,906,558
2020	7,667,090
2030	8,317,707
2040	8,823,546
2050	9,191,287

Source: Adapted from United Nations (2007a)

The main increases in global population during the 2005–2050 period are expected to occur in only eight countries. In order of population increment, these are likely to be India, Nigeria, Pakistan, Congo, Ethiopia, the United States, Bangladesh and China. Together they may account for almost half of the expected increase in global population during this period.

In the coming years, life expectancy is expected to increase and fertility rates are likely to decrease. Migration, legal or illegal, will become an increasingly important consideration, certainly significantly more important than whatever was witnessed in the recent past. For example, during 2005–2010, net migration is expected to be higher than natural increase (births minus deaths) in countries as diverse as Belgium, Canada, Luxemburg, Singapore, Spain, Sweden and Switzerland. During the same period, China, India, Indonesia, Mexico and the Philippines are expected to witness the highest rates of net emigration (United Nations, 2007a).

Another interesting trend is the increase in middle-income class (annual income levels between $6,000 and $30,000) of 2 billion people by 2030. This is expected increase pressure on and competition for local and global resources. By 2050, the middle-income class is expected to include six of the N11 countries (Egypt, Philippines, Indonesia, Iran, Mexico and Vietnam) and three of the BRICs (China, India and Brazil). These countries are likely to contribute to approximately 60% of

Table 2 Population distribution by regions, 1950, 2007 and 2050 (in percentage)

	1950	2007	2050
Africa	8.8	14.5	21.7
Asia	55.6	60.4	57.3
Europe	21.6	11.0	7.2
Northern America	6.6	8.6	8.4
Latin America and the Caribbean	6.8	5.1	4.8
Oceania	0.5	0.5	0.5

Source: Adapted from United Nations (2007a) the global GDP (Wilson and Dragusanu, 2008). The impacts of such growth rates could result in a demand for policies for a cleaner environment from an increasingly affluent population. Equally, if countries do not grow as expected and inequalities increase within countries and between regions, the environment may not become a priority concern for the population. If so, neither governments nor private sector institutions may be able to invest in cleaner practices and processes as often anticipated at present.

Ageing Population

An important factor that is now receiving virtually no attention from water managers is the rapid increase in ageing population. Globally, the population of older persons is growing at a rate of 2.6% per year, which is much higher than the annual population growth rate of 1.1%. The older population is expected to continue growing more rapidly than the population in other age groups, at least until 2050. Such rapid growth will require far-reaching economic and social adjustments in most countries (United Nations, 2007b), including significant changes in practices for managing water and other natural resources.

By 2000, the number of elderly people in the world had reached 600 million, which was nearly three times that of 1950. By 2050, this number is expected to reach 2 billion, some 22% of the entire population (corresponding figure in 1950 was only 8%). In developed countries, the number of elderly persons in 2000 was over one-fifth of their entire population. This is expected to increase to nearly one-third by 2050. In developing countries, the corresponding increase between 2000 and 2050 is estimated to be from 8% to 20%. In other words, by 2050, developing countries will have very similar percentages of elderly people as developed countries had in 2000. This will mean that the global median age will increase from 28 years in 2000 to 38 years by 2050. In 2000, Uganda had the youngest median age (15 years) and Japan had the highest (43 years).

The number of people over 80 years is projected to increase by five times, to 402 million, between 2005 and 2050. During this period, the 80-plus population in China will increase from 15.4 million to 103 million; in India from 7.8 million to 51 million; and in the United States from 10.6 million to 31 million. In other words, the 80-plus population is expected to increase at 3.9% per year, which will be more than 3.5 times the overall estimated population growth rate for this period. Thus, all the current forecasts indicate that the elderly will become an important social and political force during the post-2020 world.

Ageing population will affect the patterns of national developments and resource consumptions in a variety of ways. It will affect rates of economic growth, savings, consumptions, government revenues through taxations and expenditures, housing, health-care expenses, pension commitments and intergenerational financial transfers. In addition, compared to the earlier experience from the developed world, developing countries will be ageing at a much faster rate. This will mean that developing countries will have less time to adjust, compared to what was experienced by the developed world earlier, even though the former will have less financial capabilities, less management and administrative capacities and more efficient governance practices compared to what the developed countries had access to earlier when their population aged (Lawson et al., 2005).

The issue of an increasingly elderly population has yet to receive adequate attention in the water profession. Yet it is likely to be an important policy consideration in nearly all developing countries during the next three to four decades. Countries like India and China have at present a major demographic window of opportunity to restructure their economic development activities during the next two to three decades, with a trained, experienced and energetic workforce. However, after 2010, the number of elderly people will start to increase quite rapidly, so much so that by 2030, China will have more elderly people than the current total population of the United States (Varis, 2009).

The steady ageing of populations in East (excluding China) and South (excluding India) Asia and the two most populous Asian countries (China and India) is shown by Varis (2009) in this book. The problem of increasing elderly populations will be a complex one for all developing countries to address properly in the future. It will have major social, economic and political implications and will affect the water sector through many direct and indirect pathways.

The relationship between water management and an increasingly elderly population is completely unexplored at present. It is likely that they will affect each other in a variety of ways, only a few of which will be discussed in this chapter.

First, in the context of rural, semi-urban and peri-urban areas of many developing countries, and in the absence of water and wastewater connections at the household level, people are forced to use communal land and water bodies for hygiene purposes. For a steadily increasing number of elderly people, routine daily hygiene practices will become a serious chore, especially when physical movements become difficult or when they are sick. With improvements in health care, education and nutrition, people will be living for increasingly longer periods. Absence of water and wastewater collection facilities at home will pose particular burdens on an increasing elderly population, as well as on their families.

Second, as the older generations of people retire from work, considerable knowledge, experience and collective memory would be increasingly lost. In a country like Japan, a significant percentage of many knowledgeable and experienced people will retire from the water sector during the next 5–10 years. The overall institutional knowledge and experience levels in the water sector may decline very suddenly, and this cannot be immediately replaced by younger and newer recruits. This loss of institutional expertise and memory has already been identified as a serious issue for the water sector by the concerned ministry in Japan. This situation will become more widespread in the coming decades in both developed and developing countries.

Third, it is generally the young people who migrate to urban areas in search of better standards of living. Thus, the percentages of young people in the rural areas are likely to continue to decline, with attendant decline in the economic, social and cultural activities in the rural areas. This could accelerate the breakdown of the extended family systems. Consequently, the family support that was available to the earlier generations of elderly people would most probably continue to decline steadily. This will contribute to increasing social and economic problems in terms of deteriorating lifestyles of the elderly. It will also increase the social stress on their younger family members who may have migrated to the urban areas for a better economic future.

Fourth, in the developed countries, as the number of retired people increases, they are likely to demand better services from their water utilities. Since they will have time on their hands, they will require more information, transparency and communication from their utilities. Thus, water utilities will have to improve significantly their information and communication services with their consumers in the future. In developing countries, water utilities may have to transform themselves from primarily engineering institutions to being more akin to a service industry. This will be a major institutional transformation, which will require significant changes in the mindsets of managers and policy makers. This transformation will not be an easy task, since it is likely to be resisted by many of the existing staff members who may lose some of their power and privileges. This may create some internal conflicts within the water utilities, at least over the medium term.

Finally, virtually no research has been done on the water and wastewater requirements of the elderly and their interrelationships with water through various social, economic and cultural pathways. Unfortunately, not a single institution anywhere in the world is currently conducting serious and sustained research on these types of emerging water-related issues. These need to be studied diligently in the future.

Urbanisation

In terms of urbanisation, urban population is expected to increase from 3.3 billion in 2007 to 6.4 billion in 2050, almost doubling in a little over four decades. Urban areas will absorb all global population growth expected over the next four decades, as well as part of the rural population due to rural–urban migration and to rural settlements that will become urban centres with the passage of time (United Nations, 2007a). Globally, the rural and urban populations are now roughly in balance. However, the world population is expected to be 70% urban by 2050.

Asia has been behind Latin America in terms of the extent of urbanisation. Accordingly, countries in the Asian region are likely to witness a massive urbanisation process during the next two to three decades. While it is estimated that its rural population will remain almost stationary between now and 2025, the urban population is likely to increase by 60%.

This massive urbanisation, which is unprecedented in the entire Asian history, will present new types of water-related challenges that all developing Asian countries would have to face. The types and magnitudes of these challenges are unlikely to be similar to those experienced at present or those faced in the past. They are likely to be of a completely different character, and some of them may even be counter-intuitive. For example, considerable attention has been paid in recent years to the water and wastewater problems of the megacities (defined to have populations of more than 10 million). While megacities consume the lion's share of national resources and political interest, they represented only 3.7% of the global population in 2000 and are expected to represent about 4.7% by 2015. The percentage of population living in the next level of large cities, between 5 and 10 million, is even less: 2.8% in 2000 and expected to rise to 3.7% by 2015 (Biswas, 2006). This means that, in spite of the rate of urbanisation having increased throughout the last few decades, the highest percentages of the world population do not live in megacities and are not likely to live in megacities in the foreseeable near future. Rather, they will live in medium- or small-size cities where provision of services, infrastructure and investment will be a major challenge in the coming years (Tortajada, 2008a).

Urban centres of 500,000 or less accounted for 24.8% of the global population in 2000 (nearly seven times that of the megacities), a figure which is projected to increase to 27% by 2015. The annual average population growth rate for these smaller urban centres is expected to increase from 23.2% during 1975–2000 (comparable growth rate for the megacities was 5%, that is, less than one-quarter) to 28.2% during 2000–2015, compared to 7.5% for the megacities.

These smaller urban centres have received scant attention from national and international institutions as well as from water and development professionals, even though solving the future water and wastewater problems of these smaller urban centres will require at least as much attention as the megacities, if not more. This is because their water problems are likely to be significantly more difficult to resolve than those of the megacities since they do not have adequate financial and political power and technical and management capabilities to handle their much higher urbanisation rates. In addition, the number of these smaller urban centres is significantly higher than the number of megacities, and thus the management efforts needed for the former will be more complex and challenging compared to the latter. In fact, even though the number of people involved in smaller urban centres is 6.7 times that of the megacities and their growth rates are expected to be 4 times higher, it is a strange anomaly that they are receiving conspicuously less attention from national and international water policy makers. Clearly, unless the present policies and interest change radically, these comparatively smaller urban centres are likely to become major water and wastewater "black-holes" of the future.

Another issue worth noting is the dissimilarities in the rates of urbanisation between the megacities of the developed and developing world. For example, cities like London and New York grew progressively over nearly a century, and their gradual growth enabled them to develop effectively their water and wastewater infrastructure and their management services. In contrast, the growth rates of the megacities of the developing world like Dhaka, Jakarta or Karachi in recent decades have simply been explosive (Fig. 1). They have been unable to cope with their explosive growth rates in terms of providing satisfactory drinking water and wastewater management services. They have invariably found it very difficult to run faster just to stay in the same place.

Many of these megacities of the developing world have managed to provide water to their residents, especially to the reasonably well-off residential areas. However,

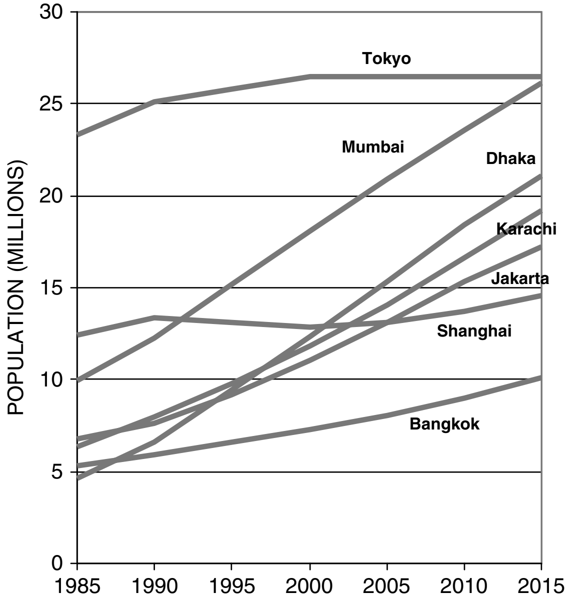

Fig. 1 Population increase in selected Asian megacities

in most cases, the services provided leave much to be desired. For example, supply is often intermittent, and water provided is undrinkable without additional treatment by the households. Furthermore, megacities have progressively fallen behind in the collection, treatment and environmentally safe disposal of wastewater generated. Wastewater may be collected from certain areas of these cities, but they are mostly discharged to nearby rivers, lakes, land or oceans without any treatment or with only primary treatment. Because of this continuing neglect of water quality management, water bodies in and around most urban centres of nearly all developing countries are now heavily contaminated, which has already resulted in serious environmental and health problems for their inhabitants. It is likely that if there is a water crisis in the future, it will not come about because of actual physical scarcity of water, as many have predicted recently, but because of continuing neglect of proper wastewater management practices. Continuation of the present trend will make available water sources increasingly more contaminated and will make provision of clean drinking water more and more expensive, as well as more complex and difficult to manage. The health and environmental costs of continuing mismanagement of wastewater collection, treatment and disposal are likely to increase significantly over the short and medium terms in much of the developing world.

Another noteworthy difference in terms of water management between developed and developing countries is that as the urban centres of the former expanded, their economies were growing as well. Accordingly, it was possible for them to have access to adequate financial resources for efficient urban water and wastewater management. For example, Japan could invest heavily in the construction of urban water infrastructure after 1950 because it was simultaneously experiencing rapid economic growth. Such extensive infrastructure development and major improvements in management practices ensured that unaccounted for water in a megacity like Tokyo could be reduced from an immediate post-war estimate of 90% to about 6% at present, making it one of the most efficient in the world. Equally, cities like Tokyo could invest heavily to control urban flooding, which would have been difficult had Japan's economy not expanded during this period.

In contrast, the rates, extent and complexities of the urbanisation process in the developing world have generally far exceeded the financial and management capacities of the national and the local governments to plan and manage the demographic transition soundly, in terms of providing clean water and wastewater management services to all of the population, efficiently, equitably, sustainably and in a timely manner. The impacts of this inadequately managed urbanisation process are manifested in extensive air, water, land and noise pollution, which is having, and will continue to have, major impacts on human health and quality of life of urban dwellers, as well as imposing major social and economic costs on their respective economies.

Another urbanisation-related problem is the sudden and fast vertical growth, especially in the central business areas, often after decades, or even centuries, of primarily horizontal expansion. This has invariably contributed to a sudden surge in population densities in such areas, with concomitant high water and energy requirements, as well as generation of high waste (wastewater and solid wastes) loads per unit area. The urban centres have simply not been able to cope successfully with such near-instantaneous accelerating demands for water and wastewater management services in the central urban areas. The problem is compounded by the prevailing unsatisfactory water supply and wastewater management services, absence of long-term planning, inadequate management, technical and administrative capabilities, lack of investment funds and high levels of corruption and nepotism.

There are, however, signs of hope. For example, in China, the importance of providing clean drinking water and proper wastewater management services has started to receive increasing high-level political attention. Because its economy has grown very substantially in recent years, the country can financially afford to provide clean water and good wastewater management services to its urban citizens. Water tariffs are rising to meet costs, and this practice has already resulted in reduced industrial water consumptions. Water and wastewater issues have become a priority consideration for national, regional and local policy makers. If such levels of political support and interest continue, it is likely that countries like China will make significant progress in urban water and wastewater management during the coming decades.

Water and Food

Water is an essential requirement for food production. As the world population continues to increase in the coming decades, higher quantities of food will be needed for human and animal consumption. Equally, as developing countries continue to make further economic progress, more people will become affluent. Accordingly, they are likely to change their dietary patterns and demand more protein products, such as meat and milk. This will further increase water requirements because animal husbandry requires more water than crop production.

Such developments do not mean that water demands for producing additional food for a larger and increasingly more affluent global population will increase concomitantly. This is because there is no one-to-one relationship between water requirements and food availability. Crop yields can be increased in a variety of different ways, including more efficient use of fertilisers and pesticides, better-quality seeds and improved management practices. In addition, the food produced should not be the only consideration. In reality, it is the food that is available to the consumers that matters the most. Regrettably, in many developing countries, 25–50% of crops, fruits or vegetables produced at present are not consumed because of heavy losses at every stage of production, transportation, distribution and storage. Reduction of these losses alone will increase food availability very significantly, without any additional water requirements. Accordingly, there are many factors that will affect the total food availability to consumers, and water is not necessarily the only factor, or the most important factor, even though many water professionals have automatically made this erroneous assumption. The numerous factors that are relevant in terms of food production and availability form a complex web of interrelationships, and the problems and their solutions are often location specific. Thus, it is often dangerous, and mostly misleading, to draw generalised conclusions on the quantity of additional water that may be needed to increase the availability of food to consumers in developing countries, without additional comprehensive studies of the overall food systems as a whole, based on reliable and representative data and correct analyses.

Agriculture is by far the major user of water in the world. In many developing countries, agricultural water use accounts for nearly 90% of total water use. However, this percentage has been declining steadily in recent years in most of the developing world, as well as the world as a whole. In contrast, industrial water requirements have been steadily increasing. Nevertheless, in absolute quantitative terms, agricultural water use in most developing countries has been increasing in recent years, and this trend is likely to continue over the medium term.

A major problem with agricultural water use has been that most countries have been pursuing incorrect or inappropriate policies for social, economic and political reasons, many of which are because of fundamental misconceptions. A good example is the energy used for groundwater pumping. Farmers in many countries at present do not pay for the actual volume of groundwater pumped for irrigation. In addition, electricity costs for pumping are very heavily subsidised by many governments. Accordingly, farmers mostly pump more groundwater than is needed for optimising crop production. In turn, this over-pumping is resulting in a steady decline of groundwater levels in many important aquifers all over the world. As the groundwater levels decline, more energy is needed to pump the same quantity of water, which requires additional subsidising of electricity costs. This has contributed to a vicious cycle of overuse of groundwater, declining aquifer levels, increasing losses to the electricity boards and increasing adverse environmental impacts (like land subsidence), none of which are sustainable on a long-term basis. Thus, major policy changes in the water and energy sectors will be needed in the future to balance water and energy uses, stabilise the levels of declining groundwater tables and reduce electricity subsidies to the farmers.

In the future, these types of intersectoral policies need to be carefully analysed, formulated and implemented. Equally, the policies in any specific sector have to be coordinated with the policies in associated sectors. The current and past practices of formulating policies in one sector without adequate consideration of and coordination with the policies in the other sectors will become increasingly costly, inefficient and unsustainable. Herein will lie a major future challenge for the world: how to coordinate appropriately all the concerned resource policies in the areas of water, energy, food and environment; the legal and regulatory frameworks necessary to support these policies; and the coordinating activities of the institutions responsible for formulating and implementing these policies. Such coordination has been very difficult to accomplish in the past because of interinstitutional problems and lack of appreciation of the increasing importance of the need for such coordination. The situation is likely to become even more complex and difficult in the future. Yet this will be an important and critical future requirement that must receive accelerated attention from the governments, research institutions and academia so that appropriate policy instruments can be formulated and implemented for specific situations.

Water and Energy

As the energy needs of the world as a whole continue to increase significantly, the water requirements of the energy sector are likely to increase as well, a fact that has mostly escaped the attention of water and energy planners. Large-scale generation of electricity invariably requires water. Without water, hydropower, an important source of electricity in many countries, cannot be generated. Equally, thermal power generation from coal, oil or natural gas requires significant quantities of cooling water. Nuclear power requires even more cooling water. If the current rate of 5–8% in annual increase in electricity consumption is to be maintained in many developing countries for the indefinite future, as is expected at present, water requirements for the energy sector need to be carefully assessed and then explicitly factored into national water policies. Already, in countries like France, the major user of water is the electricity-generating industry, and not the agricultural or industrial sectors. In the United States, thermoelectric generation represented 39% of all freshwater withdrawals in 2000, which is only a little less than agricultural water requirements (NETL, 2008).

At every stage of the water production and distribution cycle, significant amounts of energy are needed to extract, pump, transport, treat and distribute water to all users. In fact, it is estimated that 2–3% of the world energy consumption is used to pump and treat water for urban residents and industry. In more practical terms, each kilowatt-hour of electricity in the United States requires about 95 L water (E&WR, 2005).

On a global basis, agriculture consumes nearly 70% of available water supplies. There are often tensions between agricultural, domestic and industrial water users, especially in locations where supplies are already insufficient to meet the various demands under existing management practices. Consideration of water withdrawals for the thermonuclear sector, which has been ignored in most countries until now, is likely to increase the tensions further (NIC, 2008).

Use of water in energy and agricultural sectors, leading sometimes to insufficient availability of supply, often suffers from very similar problems: insufficient financial resources, inefficient usage or production, inadequate institutional arrangements, lack of coordination between the sectors, lack of long-term political commitments, inadequate human resources, insufficient community involvement, inappropriate operation and maintenance practices and also provision of insufficient information and communication with their users and consumers (Lawson et al., 2008).

According to the International Energy Agency (IEA, 2007), some $22 trillion of cumulative global investment will be necessary, in 2006 constant dollars, for energy infrastructure over the 2006–2030 period. The investment will be needed to expand supply capacity and to modernise and rehabilitate existing supply facilities. In terms of electricity, more than half of the investments in the industry will be needed for transmission and distribution networks, and the rest for power stations. Since thermoelectric energy generation (including coal, oil, natural gas and nuclear) requires large quantities of reliable cooling water, the estimated investments will require assured supplies of water (NETL, 2008).

Global economic growth will increase demand for energy, both from traditional and non-traditional sources. Globally, economic output, as measured by GDP, increased on average by almost 3% per year, from 1980 to 2005. Rapid growths in developing countries are expected to lead to a similar increase in global GDP, until 2030, resulting in higher demands for energy from all sources (ExxonMobil, 2008).

In addition to economic growth, population growth is also a fundamental driver of overall energy demand. Nevertheless, the types of energy used to meet the specific needs of the different countries depend on additional factors such as availability of supply, income levels and public policies. In 2005, global primary energy consumption was approximately 230 million barrels per day of oil equivalent (MBDOE) of fossil fuels (oil, natural gas and coal) and other non-fossil energy such as nuclear power and renewable sources. By 2030, the total energy demand of the world is expected to increase by 40%, even after assuming significant improvements in energy production and distribution efficiency (ExxonMobil, 2008).

British Petroleum (2008) has carried out a very comprehensive analysis of the consumption of primary energy in different regions of the world. According to this analysis, the consumption of primary energy (commercially traded fuels) at the global level increased by 2.4% in 2007. The IEA estimates that world primary energy demands are likely to increase by more than half between 2005 and 2030, at an average annual rate of 1.8%. Those developing countries whose economies and populations are growing the fastest are expected to account for 74% of the increase in global primary energy use, with China and India accounting for 45% (IEA, 2008). Global demand will be met by a variety of energy mixes. Nevertheless, fossil fuels will continue to provide close to 80% of global energy requirements up to 2030, with oil and gas accounting for almost 60%. Renewable energy still remains a small percentage of total global energy use, in spite of its rapid growth from 2007 (British Petroleum, 2008).

Hydropower is not a major option for future energy production in most developed countries. This is because most of the economic sites have already been developed, or are in the process of development, and because of the strong opposition from social and environmental activists. In 2007, growth in global hydropower generation was 1.7%, slightly below its historic average.

Table 3 shows the countries with the greatest annual hydroelectric energy production and installed capacities. New capacities in China and Brazil, and improved rainfall in Canada and northern Europe, offset drought conditions in the United States and southern Europe (British Petroleum, 2008).

The European Small Hydropower Industry Association has forecasted that small hydro will grow faster than large hydro, even though there is still a large dominance of large hydro in the world. Regarding large hydro, the European Union Climate Change Committee (CCC) is looking to harmonise the approval process for large hydro projects among member states and therefore regulate their sustainability and ensure that environmental aspects are taken into consideration by following international criteria. The objective is to avoid differences in transaction costs and achieve clarity and legal certainty in the carbon trading market so that projects from any member state receive equal treatment (De Brauw et al., 2008). While this is a welcome step towards making carbon credits available from large hydro projects, it is not abiding. Each EU member state has discretionary power when assessing the admissibility of project-based credits.

Table 3 Hydroelectric production and installed capacity in 2006: top eight countries

Country	Annual hydroelectric energy production (terawatt hours, TWh)	Installed capacity (GW)
China	416.7	128.57
Canada	350.3	68.974
Brazil	349.9	69.080
USA	291.2	79.511
Russia	157.1	45.000
Norway	119.8	27.528
India	112.4	33.600
Japan	95.0	27.229

Source: British Petroleum (2008)

Thermoelectric Generation

Water availability is a regional and national concern for meeting future power generation needs. In addition to human consumption, irrigation and industrial development, environment has become an important competitor for the use of water resources, which in turn has an impact on water available for other uses including power generation. Finding viable locations for thermoelectric power plants will become increasingly challenging with time because of tradeoffs needed between energy, environment and water security, as well as land use, economic, social and political considerations.

In the United States, thermoelectric generation represents the largest percentage of electricity production, with coal-based power plants accounting for about half of the electric supply at the national level. The National Energy Technology Laboratory (NETL) of the Department of Energy of the United States has been conducting research on water conservation and management strategies to develop practical solutions to conserve water resources, minimise impacts on water quality and provide environmentally sound solutions for increasing national energy security through domestic resources, for thermoelectric power plants (Feeley, 2004; NETL, 2006). Given that the thermoelectric-generating capacity in the United States is expected to increase by 18% between 2005 and 2030 (EIA, 2008), reliable availability of freshwater in terms of quantity and quality has to be an important consideration.

A fundamental approach for the future has to be to make existing and future thermoelectric power-generating plants more efficient in terms of their water requirements. In the United States, water withdrawals for this sector increased from 492 billion litres per day in 1995 to 553 billion litres per day in 2005. In the future, a determined attempt has to be made to develop advanced technologies that enable the use of alternate sources of cooling water and reduce evaporative and/or drift losses from existing wet cooling towers in order to achieve significant savings in freshwater withdrawal. In the United States, in spite of technological and management advances, thermoelectric power generation will remain a major water consumer for the foreseeable future. Depending on the advances made in technology and management practices, water withdrawal from the sector is likely to range between 424 and 583 billion litres per day by 2030. Since the national water consumption in the country is expected to increase in the future, this will result in increasing competition for water resources (Feeley et al., 2008; NETL, 2008).

The increasing importance of compromises and tradeoffs between various sectors can best be illustrated by the following examples from the United States (NETL, 2008):

> Power Generation Facility Siting Concern about water supply, expressed by state regulators, local decision-makers, and the general public, is already impacting power projects across the United States. For example, in March 2006, an Idaho state House committee unanimously approved a two year moratorium on construction of coal-fired power plants in the state based on environmental and water supply concerns. Arizona recently rejected permitting for a proposed power plant because of concerns about how much water it would withdraw from a local aquifer. In early 2005, Governor Mike Rounds of South Dakota called for a summit to discuss drought-induced low flows on the Missouri River and the impacts on

irrigation, drinking-water systems, and power plants. A coal-fired power plant to be built in Wisconsin on Lake Michigan has been under attack from environmental groups because of potential effects of the facility's cooling-water-intake structures on aquatic life. In February 2006, Diné Power Authority reached an agreement with the Navajo Nation to pay $1,000 per acre foot and a guaranteed minimum total of $3 million for water for its proposed Desert Rock Energy Project. In an article discussing a 1,200 MW proposed plant in Nevada, opposition to the plant stated, "There's no way Washoe County has the luxury anymore to have a fossil-fuel plant site in the county with the water issues we now have. It's too important for the county's economic health to allow water to be blown up in the air in a cooling tower."

Biofuels

Increasing biofuels production can have impact on overall agricultural production, land-use patterns, water use and water quality, depending on which crops are grown, and where, and on the agricultural practices and technology used. Biofuels have enjoyed enormous support during the past years, mainly in the United States (corn based) and Brazil (sugarcane based). In contrast, biodiesel production dominates in Europe, with an important contribution from Germany. The key drivers for the growing interest in biofuels have been its direct substitution for fossil fuel and high subsidies provided to the farmers. However, this sector may face serious constraints to growth in the future due to potential uncertainties such as long-term supply of biofuels feedstock; land, water and environmental constraints; levels of agricultural commodity and oil prices; and the extent of subsidies available from the various governments. Growing biofuel demands in recent times have provided farmers with a greater economic incentive to grow crops for biofuel production, which has contributed to reduced food production and higher food prices.

For present and future use of biofuels, and thus water needed for its production, there are important factors that have to be considered such as subsidies, performance and technology-related targets (e.g. renewable portfolio and renewable fuel standards), tax credits, cap and trade frameworks, carbon taxes, loans and grants (Goldman Sachs, 2007). In the United States, subsidy policies on biofuels have focused primarily on energy security and secondarily on providing support to farmers as part of the overall farm policy. Since biofuels production has been considered to be an important component of the US energy portfolio, its production has been encouraged through the Energy Act of 2005, continuation of the ethanol subsidy at $0.135/L ($0.51 per gallon) and direct payment to farmers for corn and soybeans through the Farm Bill. The US Department of Energy has estimated that biofuels, ethanol and biodiesel from all feedstocks will be able to provide 30% of transportation fuel by 2030 (National Research Council of the National Academies, 2008).

Over the last decade, the US government has implemented a range of both supply- and demand-side incentives intended to increase biofuel production. The supply-side incentives have included grants, loans and loan guarantees as well as the federal Volumetric Ethanol Excise Tax Credit, which provides ethanol blenders/retailers with a $0.135/L ($0.51 per gallon) of tax credit, and a tax credit of up to 30% of the cost of alternative refuelling property, up to $30,000 for business property. Biodiesels receive a credit of $1 per gallon. The US Department of Agriculture manages a programme that provides grants, loans and loan guarantees to ranchers and rural small businesses for the development of alternative energy projects such as the construction of biofuel plants. The US Department of Energy has allocated a programme that allots $2 billion per year to biofuel loan guarantees. The main demand-side incentive is the Renewable Fuel Standard, which requires that increasing amounts of biofuels be blended with gasoline, from 15 billion litres in 2006 to 28 billion litres in 2012 (Goldman Sachs, 2007).

While the main biofuel used in the United States is now ethanol derived from corn kernels, it is expected that ethanol from cellulosic plant sources (corn stalks and wheat straw, native grasses and forest trimmings) may be used commercially within the next decade because of technological breakthroughs. The National Research Council of the National Academies (2008) considers that during the next 5–9 years, increased agricultural production of biofuels is unlikely to have significant impacts on water quantity at the regional and local levels, except in places where water availability is already a constraint. In terms of water quality impacts, these are expected to be in terms of pollution due to increasing use of agricultural chemicals and to soil erosion. These impacts can be partially mitigated by using appropriate agricultural practices and technologies that are already available.

Biofuel production will require more and more water in the future if this subsector expands, as some expect at present. As the use of agricultural chemicals like pesticides and fertilisers increases to improve the yields of the biofuel crops, water bodies around such production systems may witness higher levels of nonpoint pollution, which has proved to be significantly more difficult to control compared to point sources of pollution, even in developed countries. Accordingly, the production and processing of the biofuel crops are likely to bring with them attendant water quantity and quality implications. As long as these implications are clearly thought through in terms of their social, economic and environmental impacts, and appropriate remedial measures are implemented as and when required, the problems may be manageable. However, as of now, virtually no country has carefully analysed the water, land, environmental and social implications of increasing biofuel production and then made appropriate policy decisions.

It should also be noted that, just as the energy sector requires large quantities of water, the water sector is an equally important user of energy for its own operation. Energy requirements for pumping are already very significant in nearly all countries. As the number of water and wastewater treatment plants increase exponentially in the coming years, especially in the developing world, the energy needed for their proper operation and maintenance will also increase. Thus, the water and energy sectors will be even more closely interlinked in the future than they are at present, which will require increasing coordination of policies related to the management of these two sectors, requiring many tradeoffs and compromises.

Water and Environment

The implications of environmental management policies on water development and management have received increasing attention during the past four decades, when it was realised that water and environment policies affect each other in many significant ways, sometimes positively, but at other times adversely.

During the early part of the global environmental movement, the primary focus was on how to stop all types of pollution. For example, during the United Nations Conference on the Human Environment, held in Stockholm in 1972, the main water-related environmental concerns considered were preventing water pollution and impacts of acid rain on forests and lakes. Later on, a backlash developed from certain sectors of society on all types of large infrastructure development projects. This was especially relevant for the construction of large dams and irrigation projects. In this "small is beautiful" era, all large development projects attracted considerable criticisms because of their potential adverse impacts, some of which were justified, but some of which were also fictional.

During the 1980s and 1990s, large water development projects from all over the world came under considerable criticisms from social and environmental activists and many nongovernmental organisations (NGOs). This movement probably reached its peak with controversies associated with the construction of some large dams like Sardar Sarovar and Tehri dams in India, Arun II dam in Nepal and the Nagara Barrage (to prevent saltwater intrusion) in Japan. These controversies had both positive and negative impacts on future water management practices, some of which will be briefly discussed next.

On the positive side, many social and environmental considerations that had not been adequately addressed earlier started to receive accelerated attention. Environmental and social impact analyses became the norm rather than exception, and issues like involuntary resettlements and adverse environmental and ecosystem impacts due to large infrastructure development projects became important considerations. Indeed, the pressure from certain sectors of society was such that not only did the earlier shortcomings receive considerable attention, but also planners and policy makers were forced to respond to them promptly and adequately. Consequently, many undesirable aspects of development activities were properly considered and often appropriate ameliorative actions were taken. This probably would not have happened within a short timeframe of only two decades unless concerted opposition had materialised on the construction of such large development projects.

On the negative side, this opposition to large projects ensured that some water development projects that should have been constructed for poverty reduction, employment generation and raising the living standards of the people were seriously delayed. This opposition further contributed to reduction in funding support to water projects from international sources because of the controversies surrounding them, which consistently received adverse national and international media attention. For some unexplained reasons, large water development projects attracted more controversy than other types of development activities. Donors became very reluctant to fund water projects, irrespective of their overall needs and benefits during the 1980s and 1990s.

The discussions started to become more balanced during the post-2000 period. It is now increasingly realised that water development projects must receive priority attention in all developing countries, not only to satisfy domestic and industrial needs, but also to improve food and energy security of the nations. Equally, however, these structures need to be planned and managed in such a way that they are technically feasible, economically efficient, socially acceptable and environmentally friendly. In future, many tradeoffs and compromises will have to be made between all these and other associated requirements since they are not mutually exclusive. This will be a major challenge.

As societal perceptions have changed and the knowledge base to plan and manage water infrastructure has increased significantly, it is now possible to improve the earlier planning and management practices significantly by concurrently maximising the positive economic, social and environmental impacts, minimising the negative impacts and ensuring that the people who are likely to pay the costs of the projects (e.g. those who have to be resettled involuntarily) are explicitly made the direct beneficiaries of the projects. With this changing mindset and better understanding and appreciation of environment–development links, it is likely that the overall discussion of water development and environmental issues will become more objective and less polarising in the future.

While the adverse social and environmental impacts (real or imaginary) of large water developments have received considerable attention from the media and policy makers, another environmental issue has undeservedly received somewhat benign neglect. This is increasing water contamination from point and nonpoint sources because of accelerating domestic, industrial and agricultural activities all over the world. There is no question that water quality management must receive accelerated attention in the future.

Similarly, provision of clean water supplies has received considerable attention from policy makers in developing countries and from national and international institutions, but commensurate interest in wastewater collection, treatment and disposal has often been conspicuous by its relative absence. Regrettably, there are only limited signs that this attitude is starting to change. In the coming decades, proper management of wastewater from domestic and industrial sources must receive as much attention as water supply, if not more, because of the inadequate consideration in the past.

Increasing water pollution from all sources is a major issue for nearly all developing countries, and control of nonpoint sources of pollution is an urgent requirement for all developed and developing countries. Unless the present perceptions and attitudes change radically during the coming decades, water quality management will become a very critical issue for the future. This is because, at the domestic level, nearly all the water that enters any household is eventually discharged as wastewater. Accordingly, introduction of new sources of water to an area, without adequate provision for treating the wastewater, which the introduced water will invariably become, will be only storing up problems for the future.

Even in the many urban centres of the developing world where wastewater is collected through sewer systems, it is often discharged to freshwater bodies, land or oceans with only limited, or even no, treatment. This means that the problem of wastewater contamination is not being solved: it is simply being transferred from one location to another. The underlying implicit philosophy has been somewhat akin to “out of sight, out of mind”.

Compared to domestic wastewater disposal, the situation is becoming even more serious and complex with industrial wastewater discharges, which, for the most part, receive inadequate treatment in nearly all developing countries. At present, few urban centres in developing countries have functional secondary and tertiary industrial wastewater treatment plants. Primary wastewater treatment plants are often nonfunctional for significant periods of time because of poor design, inadequate management, lack of political interest and funding, public apathy and many other associated causes. Even when these plants do function, most operate below their design efficiencies. Since domestic wastes are primarily organic, they degrade over a limited time. However, the situation is more complex and serious for industrial wastes, which contain significant amounts of substances that may be toxic to human beings and ecosystems and which are not easily biodegradable.

With fast industrial and urban growth, proper wastewater management is rapidly becoming a serious social, economic and human health issue in nearly all developing countries. In addition, as the nearby surface water and groundwater sources for urban centres are becoming increasingly contaminated with domestic and industrial wastes, these bodies will require higher levels of treatment before they can be safely used as sources for drinking water downstream. The treatment processes needed to decontaminate polluted sources are likely to become increasingly sophisticated and expensive in the coming decades, which may not be an attractive or feasible alternative for many urban areas because of economic and technology management constraints.

The previous discussion refers only to point sources of contamination from domestic and industrial users: nonpoint sources are at present almost totally neglected in developing countries and inadequately managed in developed countries. The use of agricultural chemicals in many developing countries is still somewhat limited. Accordingly, nonpoint sources of pollution are still not as serious as point sources. However, as there is increasing emphasis on increasing crop production per unit area to enhance both farmers’ incomes and food security, more and more agricultural chemicals are likely to be used in the future by farmers in developing countries. This will further aggravate the water quality conditions, because control and management of nonpoint sources of pollution are very complex and difficult tasks under the best of the circumstances. Even the most developed countries, like those belonging to the European Union as well as Japan and the United States, have found it very difficult to manage nonpoint sources of pollution. Agricultural chemicals, which are extensively used in developed countries, leach into the rivers which ultimately carry them to the estuaries, increasing concentrations of agrochemicals in the estuaries and the oceans around them. Consequently, worldwide, more dead zones in the estuaries of major rivers like the Mississippi are being observed, and many of these dead zones are expanding with time. In the coming years, reduction or even elimination of the dead zones through effective management of nonpoint sources of pollution will be an important consideration.

In a macro-global sense, a major challenge facing developing countries is how quickly and efficiently current wastewater management practices and processes can be substantially improved. Considering the cost of construction and efficient operation of wastewater management plants, and the number of trained and experienced personnel needed to manage them, ranging from managers to plant operators and technicians, who are mostly not available at present, resolution of this problem in the foreseeable future will be a most difficult task.

Another macro issue in the water and environment area of the future is likely to stem from the increasing acceptance of the concept of environmental flows. Many countries have now accepted, or are in the process of accepting, that the environment is a legitimate user of water. This means that certain quantities of river flows should be earmarked for environmental and ecosystem uses.

It is highly likely that in the foreseeable future there will be increasing acceptance of this concept in the world as a whole. This will present two types of problems: one conceptual and the other practical. At the conceptual level, considerable additional research needs to be conducted on how environmental flows of rivers can be reliably estimated for both perennial and ephemeral rivers for various regions with different climatic regimes, physical and ecosystem conditions, social and economic situation of the people and many other associated conditions. The development of methodologies to reliably estimate environmental flows under differing conditions has to be an important requirement for the future.

At the practical level, available amounts of water in many rivers have already been allocated and, in many cases, over-allocated, especially during dry seasons and drought periods. Under such conditions, new allocations of water to the environment will mean that some of the existing allocations to domestic, industrial and agricultural sectors will have to be reduced, which will be a difficult task because of social, economical and political reasons. In addition, for transboundary rivers, as well as interstate rivers in federal countries like Brazil, India, Pakistan and the United States, this will raise new sets of legal and institutional issues, especially when inter- and intra-country treaties already exist for water allocations to various state parties. Considering it often takes 20 years or more to negotiate new water allocation treaties for transboundary and interstate rivers, implementation of the concept of environmental flows in such water bodies may prove to be a complex, difficult and time-consuming task.

Finally, environmental impacts of natural disasters on water and wastewater infrastructure cannot be ignored. As much as possible, infrastructure has to be designed to withstand floods, earthquakes and other natural disasters like tsunamis and storm surges. In other words, future water–environment interactions must be viewed through a much broader conceptual framework compared to what is being practiced at present. Appropriate implementable frameworks thus need to be developed.

Technological Advances

Like climate change, technological developments are likely to introduce another set of uncertainties in water management practices and processes. However, unlike climate change, technological developments are much more likely to bring positive surprises in numerous aspects of water development and management.

The information and communication revolutions have had radical impacts on water. Management and analysis of water-related data have become a far simpler and more economic and efficient process than ever before in human history. Information storage, retrieval and exchange have improved exponentially in recent years. South–South knowledge transfer, which was in its infancy some 25 years ago, has now come of age because of tremendous advances in information management and exponentially declining costs. In future, such advances are likely to progress even further. These developments will unquestionably have significant implications for the water sector, including more effective ways to conduct sustainable communications and interactions with the various stakeholders on a regular basis.

Another area that will have a major impact on water-use patterns will be biotechnological advances. These advances will help in the development of pest- and drought-resistant crops, as well as crops that can be grown in marginal-quality water, like saline water. The net impacts of these likely developments may be that more crops can be grown with lower quantities of water and also with the use of marginal-quality water.

Biotechnology is likely to help in many other ways. For example, a new variety of rice under field trial at present can survive for 3–4 weeks under flood water. Every year, hundreds of thousands of tons of rice crops are lost due to prolonged submergence under flood water. These new varieties of rice crops will be able to withstand most flooding.

Similarly, biotechnology is making rapid advances in wastewater treatment. It is highly likely that there will be further very substantial improvements and breakthroughs in these areas during the coming decades. These could have profound effects on water quality management, which is now a very serious problem nearly all over the developing world.

Another area where technological developments have made remarkable progress during the past decade is in desalination. Reduction in desalination costs has made this an important alternative for increasing water availability for both domestic and industrial sectors. By using the new generation of membranes and improved management practices, seawater desalination costs have fallen by almost a factor of three during the past decade. At the current cost of producing desalinated water (around \$0.45–0.60 per m^3) through reverse osmosis, the technique has become cost-effective for many cities where water availability is a constraint. The cost of treating brackish water has become even lower: \$0.20–0.35 per m^3, depending on its salt content. The technological and management breakthroughs achieved are making desalination a viable alternative for solving water quantity and quality problems for domestic and industrial uses, especially for coastal areas. However, there are many other factors like energy availability, technology management and environmental considerations (especially disposal of brine), which need to be carefully assessed before desalination practices can be successfully and extensively used on a sustainable basis in any country. Desalination-related issues have been discussed in greater detail in a later chapter of this book.

The water profession, in general, has not fully appreciated the potential applications of technological advances which are likely to change water use and demand patterns very significantly. An important reason for this non-appreciation is that water managers have very little, if any, regular contact with professionals from other sectors like biotechnology, information and communication technology and desalination where these developments are taking place and which are likely to influence how water will be managed in the future. Extensive interactions with such professions will be an essential requirement for the future.

However, even when the new technologies become available and cost-effective, national capacities to manage them properly need to be developed. Capacity building for managing water resources in the coming years, in spite of considerable rhetoric, is still not receiving enough attention in most countries. It should be realised under rapidly changing global conditions that tomorrow's water problems can no longer be identified, let alone solved, with today's knowledge and yesterday's experience. A whole new mindset will be needed to identify and solve future water-related problems, which will require substantial attention and additional investments to capacity building.

All the existing and likely future trends indicate that there will be extensive technological advances that will significantly contribute to the solutions of many of the future water problems of the world. Equally, there will be new sets of constraints for timely technology adoption that will have to be overcome. Both the opportunities and constraints may differ from country to country and even within a country, and technological solutions may be location specific. Those countries that will make a determined attempt to adopt emerging technologies to solve their water-related problems will make remarkable progress in assuring water security. In principle, availability of appropriate quantity and quality of water should not be a constraint for them to improve human welfare.

Planning for Uncertainties and Unexpected Developments

Uncertainties associated with efficient water management have increased substantially over the past decade due to factors over which the water sector has control (such as regulations, technologies and demand patterns) as well as those over which the water professionals at best may have only limited control. Water management in the future will thus have to be carried out under increasingly uncertain conditions.

One example of such uncertainties is climate change, a main global concern at present. Irrespective of all its uncertainties, climatic changes and/or fluctuations harbour the risk of a growing number of extreme weather conditions and catastrophes whose social and economic impacts could be very significant and likely to increase with time. In most countries, natural disasters disrupt the normal process of economic development. Developing countries already suffering from resource and capacity constraints are often forced to divert their limited resources from ongoing development activities to immediate relief-and-rescue operations because of disasters, which can sometimes set back their development plans by as much as a decade (Grabs et al., 2007). During the last 50 years, climate-related losses have increased very significantly, with the trend becoming more marked since about the mid-1980s. For example, mean annual economic losses caused by major climatic-related catastrophes increased from $12 billion to $40 billion during the 1990s (Munich Re Foundation, 2007). The drought of the early 1990s in Zimbabwe was associated with an 11% decline in GDP; the recent floods in Mozambique led to a 23% reduction in GDP; and the drought of 2000 in Brazil cut the projected economic growth by half (Lenton et al., 2005).

Another uncertainty stems from economic growth and the impacts of massive energy-related developments of newly emerging economies such as BRICs, as they become major economic and trade partners, competitors, resource users and polluters. These are on a scale that was previously unthinkable. Their implications for the water sector are still only partially appreciated and understood, but it is clear that the effects have transcended their national boundaries. The increasing social and environmental pressures are being felt mainly by developing countries at present because they are less equipped than developed countries to make the necessary financial and institutional adjustments within limited timeframes. Even for developed countries, these changes have largely outpaced the benefits of any efficiency gains that have been witnessed in recent years. New and innovative policy actions are thus urgently needed for more efficient management of natural resources, including water, for both the developed and developing world (OECD, 2008).

At a local level, institutions will be forced to respond to social and economic uncertainties. For example, water utilities will have to increase their efficiencies to respond to the needs of more active and demanding consumers than ever before and also to the wishes of their political masters, who in turn will be reacting to societal demands for better services, perhaps with a time lag. Planning for the provision of good and acceptable water services will include consideration of many different types of uncertainties, among which will be population growth and structure (which may translate into additional resource requirements and different contaminant loads), changing political landscape (including increasingly important roles of NGOs and other civil society organisations in the formulation and implementation of public policy decisions), regulations in a highly politicised environment, nature of the workforce (including retirement of skilled and experienced workers), increasing and more effective use of existing and new technology, utilisation of new sources of water through desalination or reuse of treated wastewater, use of marginal-quality water, financial management including using water tariffs to finance and manage infrastructure, and managing cost of energy, which will remain a large component of the cost of production and distribution of water and disposal of wastewater (Jeans et al., 2005).

In terms of public participation, the involvement of multiple actors with diverse interests in water management, along with the increasing importance of issues such as responsibility, accountability, transparency, equity, fairness and corruption, will further increase the complexity of water management from the global to the very local levels. To these uncertainties have to be added a continuing overall deficit in terms of issues like good governance, efficient institutions, adequate and timely financial investments and political will (Tortajada, 2008b). Together, these factors are as much a cause of global water imbalances and driving forces as are trends in population growth, urbanisation and economic development.

Even though water institutions all over the world are facing increasingly uncertain conditions, solutions still remain mostly traditional. So far, advances have been mostly incremental. Examples include many past strategies to water quantity and quality concerns which have been narrowly focused without appropriate consideration of their financial viabilities on a long-term basis; urgently needed water pricing reforms, which are often missing; absence of effective public–private partnership; regulatory frameworks that do not encourage efficiency or innovation; and infrastructural developments that continue to neglect poverty alleviation. In addition, there are continuing shortcomings with technology absorption and adoption processes, capacity building and forward-looking education, training and research programmes.

The global water community must engage more actively on issues related to knowledge generation and synthesis from different parts of the world, not only from within the water sector, but also from *outside*, since these will have a bearing on water management in the future. This should include consideration of appropriate policy options to solve key water-related problems due to their increasingly complex, and often cross-sectoral, nature, but always within the framework of social and economic development of the country concerned. Different actors need to work together to ensure the formulation and implementation of coherent water management policies by considering the problems of the future, rather than focusing on issues of the past which may no longer be important or relevant. Ensuring improved and sustained communication between a multiplicity of groups having different interests and agendas, dissimilar ethics, values and norms and absence of an overall consensus about the types of goals that are to be pursued will present formidable challenges that will require extraordinary measures of coordination, collaboration and cooperation which simply do not exist in the water sector at present. All these issues will further increase the uncertainties associated with water management processes in the future.

One of the most important requirements for the future for both developed and developing countries will be accelerated priority attention to water quality management. Each year, the numbers of people who are affected at the global level by water-borne diseases are estimated to be in the order of millions, and the related costs are likely to be in the order of billions. However, there are very few studies available at present which can be considered to be definitive because of their methodological and data constraints. The estimates that are available at present are mostly based on simplistic and erroneous assumptions and poor quality data: they are highly likely to be very wide off the mark.

The Third World Centre for Water Management has carried out analyses for Mexico (Marañón-Pimentel, 2009). According to this study, in 2005 alone the costs due to water-borne diseases in the country were estimated to be $260 million, with the highest mortality rates in population between 0 and 4 years and above 65 years. Nevertheless, and in spite of the economic importance of the impacts that waterborne diseases have had in the country for decades, these costs have never been estimated reliably by the various governmental institutions or academia.

Furthermore, widespread mistrust of the quality of tap water that is provided all over Mexico has ensured that all levels of the society are paying high economic and social costs in terms of access to clean drinking water, irrespective of their socioeconomic status. Drinking water for much of the population, even when they have access to tap water, comes mostly from 20-L containers which are sold commercially and whose quality is also questionable (Marañón-Pimentel, 2009).

The perception of the population that the quality of tap water is not suitable for drinking has had an enormous impact on the economy of the country. In 2007, Mexico became the largest per capita consumer of bottled water in the world, with total consumption increasing from 11.6 billion litres in 1999 to 22.33 billion litres. At present, per capita bottled water consumption in Mexico is nearly twice that of the United States, even though its per capita GDP is about one-sixth that of the United States.

It is not only the economic costs of bottled water that the consumers are forced to bear in countries like Mexico, India, China or Brazil because the quality of domestic water supplied leaves much to be desired, but also the social and environmental costs that are quite high. For example, worldwide, it is estimated that 2.7 million tons of plastic are used annually by the bottled water industry. Energy requirements for the production and distribution of the products are high. Environmentally sound disposal of the empty bottles is a problem in nearly all developing countries.

With present knowledge, management practices and technology available, there is absolutely no reason why important urban centres of countries like Mexico, India, China, Brazil or Egypt cannot be provided with clean drinkable water on a 24-hour, 7 days a week basis. Much of the funding needed to provide 24 $\times$ 7 water supply is already available but, most unfortunately, such funds are not being efficiently used at present. The main reasons for this unsatisfactory performance of the water utilities is continued poor governance; lack of realisation by the policy makers that water quality is an important issue for health and environmental reasons and that the problems are solvable; and public apathy, extensive political interferences, inappropriate institutional structure and widespread corruption. A major future uncertainty will stem from how long it will take the public in developing countries to demand, and then get, drinkable water supply and acceptable levels of water management. Until the existing public apathy disappears, bureaucrats and politicians will continue to give lip service to the importance of proper urban water management, which will mean that the likely improvements in the future will be mostly incremental. The economic, social and environmental costs will continue to increase, and an apathetic public will continue to accept the poor services offered. The events that will trigger the changes whereby the public will forcefully demand better water-related services, and the timeframes over which such changes are likely to occur in different regions, are very difficult to predict at present.

Final Reflections

Projections of future population and consumption trends indicate that demands for water of appropriate quantity and quality for various uses will be an issue for all regions, in both developed and developing countries. Drivers such as urbanisation, population, industrialisation and economic development and the corresponding rises in the demands for food, energy and environmental security are just a few of the trends that will seriously affect existing water planning, management and allocation processes.

Degradation of natural resources, including water, has been due to continued mismanagement and poor governance. Extensive policy and market failures have received limited corrective actions from the concerned institutions over the past decades. Rapid urbanisation, industrialisation and economic growth have imposed complex demands not only on the environment but also on the human and the institutional abilities to respond to such needs efficiently. The net result has been misuse and over-exploitation of resources in most countries of the world. There is now an urgent need to formulate forward-looking, business-unusual water policies and strategies that can reform and strengthen public institutions, increase public and private sector investments, manage urban and rural environments, encourage use of available and appropriate technologies, seriously consider South–South technology transfer and develop a new generation of capable managers and experts representing various appropriate sectors and disciplines with good communication skills.

Given the previously discussed constraints, trends and drivers, new visions for water futures need to be formulated for national, regional and local levels. While there is likely to be some common elements for the formulation of these futuristic visions, each one of them has to be developed for specific conditions. These visions should be developed for at least 10–20 years, which will be a radical departure from the current practice where the plans are for 4–6 years. Furthermore, in the past, as well as at present, water management policies and plans have been mostly framed narrowly on a sectoral basis, with very limited consideration of future drivers from other sectors that are likely to affect the water sector. There is continuing emphasis on short-term solutions based on past experiences and prevailing bandwagons, which are unlikely to provide the right long-term solutions for the new generation of emerging water problems.

On the basis of the analyses carried out at the Third World Centre for Water Management, it can be said with considerable confidence that, as the twenty-first century progresses, the water profession will face a problem the magnitude and complexity of which no earlier generation has had to face. The profession at present faces two main choices: carry on as before with a business-as-usual and incremental attitude and endow future generations with a legacy of poor water governance and a plethora of partially resolved water-related problems or continue in earnest an accelerated effort to identify, understand and then efficiently manage the likely problems of the future, in order to ensure that the world's water resources are properly managed on a long-term basis for the benefit of the entire humankind.

All the major issues facing the world will become increasingly interrelated. The dynamics of the human future will not be determined by any one single issue but by the interactions between a multitude of issues. Increasing population, urbanisation, globalisation and standard of living will require more food, energy and other efficient raw materials, as well as their management which must be significantly more efficient than ever before. Assuring food, energy and environmental securities will necessitate good water governance on a long-term basis. The common requirements for all practical responses to the solutions must include greater and efficient investments; use of more knowledge, technology and expertise; eschewing of dogmatic and/or solution-in-search-of-a-problem approaches; functional institutions; and intensified cooperation and coordination between sectors as well as within countries and between countries.

The interrelationships between these issues are global in character, and hence they can probably be best understood, and then resolved, within a global framework. While the framework may be global, within this there must be a wide variety of well thought through and coordinated national and local responses. Water problems of the future need to be viewed, analysed and solved within global, regional, national and local frameworks. This will be a radical departure from the existing practice.

The water profession should realise that the world is heterogeneous, with different physical attributes, economic and climatic conditions, cultures and social norms, availability of natural resources, management capacities, and institutional arrangements. The systems of water governance, legal and institutional frameworks and modes of decision-making may often differ from one country to another in very significant ways. Under such diverse conditions, one fundamental question that the water profession must ask is whether any single management paradigm can encompass all countries in the future, as often implicitly assumed at present. Can any single paradigm be equally applicable, both now and in the future, for Asian values, African traditions, Japanese culture, Western civilisation and Islamic customs? Can any general paradigm be equally valid for monsoon and non-monsoon countries, deserts and very humid regions? The answers to these questions are likely to be negative. This means that many of the water management paradigms that are popular at present are unlikely to be very useful in the future.

The world is changing very rapidly, and with it the current water management practices must change as well. The types and nature of future water problems must be carefully anticipated and then objectively analysed in the light of the expected changes. In the final analysis, it is deeds and not rhetoric or dogmatic beliefs that will be most important in solving future water problems. Past or current solutions are unlikely to shed meaningful light on the coming, new, turbulent and uncertain world of water management.

During the next two decades, policy makers will have to juggle regularly with the competing, conflicting and changing needs of water for different purposes and by various stakeholders, as well as to coordinate effectively the increasing needs of concurrently assuring water, energy, food and environmental securities in order to maximise human welfare. Water will be one of the important common threads that will bind all the four concerns. The task facing the water profession will be historically unprecedented and will make proper adequate understanding of all the different pathways of interlinkages between different sectors, users and interests, numerous cause-and-effect interrelationships and a series of implications and consequences that will be very difficult to forecast and analyse and even more difficult to manage under constantly changing conditions.

There is now a revolution taking place in water management, even though most professionals may not be aware of it. In the wake of this revolution, long-held concepts and models of water management are likely to evolve further in an accelerated manner, and some may even disappear completely. Never before in human history has water management faced so many profound changes within such a short period of time, as are likely to be witnessed during the next two to three decades. How to anticipate and manage these expected changes successfully and in a timely manner will be a major challenge that the water profession must meet. In this connection, it will be desirable to heed the advice of the eminent eighteenth century British statesman and philosopher Edmund Burke: "never plan for the future by the past". In the twenty-first century, Burke's advice will be more prophetic than ever.

References

Biswas AK (2006) Water management for major urban centres. In: Varis O, Tortajada C, Lundqvist J, Biswas AK (eds) Water management for large cities. Routledge, Abingdon, pp. 3–17

Biswas AK, Tortajada C (2009) Hydropolitics of Aswan High Dam, water resources development and management book series (Biswas AK, Tortajada C (eds)) Springer, Berlin (forthcoming)

British Petroleum (2008) BP Statistical review of world energy, June 2008. Available at http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622

California Department of Water Resources, California Water Plan (2005 and 2009) Updates. Available at http://www.waterplan.water.ca.gov

De Brauw, Blackstone and Westbroek (2008) Emission Trading: Proposed EU harmonisation of large hydro criteria. De Brauw Legal Alert, May 2008. Available at http://www.debrauw.com

E & WR (2005) In: CSIS. Global water futures. Addressing our global water future. Center for Strategic and International Studies, Sandia National Laboratories, California

EIA (2008) Annual Energy Outlook 2008 with Projections to 2030, Energy Information Administration. http://www.eia.doe.gov/oiaf/aeo/index.html

ExxonMobil (2008) The Outlook for Energy: A View to 2030, Irving, Texas. Available at http://www.exxonmobil.com/Corporate/energy outlook.aspx

Feeley TJ III (2004) Responding to emerging power plant-water issues, DOE/NETL's R&D Program, Presentation at the American Coal Council 2004 Spring Coal Forum, Dallas, Texas, May 17–19, 2004

Feeley TJ III, Skone TJ, Stiegel GJ Jr, McNemar A, Nemeth M, Schimmoller B, Murphy JT, Mandredo L (2008) Water: a critical resource in the thermoelectric power industry. Energy 33:1–11

Goldman Sachs (2006a) Looking Forward to 2007 and Beyond. CEO Confidential, Global Economics, Issue 2006–10, December 1, 2006

Goldman Sachs (2006b) Building the World: Opportunities in infrastructure. CEO Confidential, Global Economics, Issue 2006–2006, June 15, 2006

Goldman Sachs (2007) Alternative Energy: A Global Survey. Global Markets Institute, Fall 2007. At http://www2.goldmansachs.com/citizenship/global-initiatives/research-andconferences/past-conferences/alternative-energy-docs/global-survey.pdf

Goldman Sachs Global Investment Research, Nuclear Energy Overview (March 2007). In: Goldman sachs, Alternative energy: A global survey, Fall 2007, New York

Grabs W, Tyagi AC, Hyodo M (2007) Integrated flood management. Water Sci Technol 56(4): 97–103

IEA (2007) World Energy Outlook: China and India insights. International Energy Agency and Organisation for Economic Co-operation and Development, Paris

Jeans EG III, Ospina L, Patrick R (2005) The primary trends and their implications for water utilities. J Am Water Resour As 97(7):64–77, July

Lawson RL, Lyman JR, McCarthy ER (2008) A 21st century marshall plan for energy, water and agriculture in developing countries. Policy paper. The Atlantic Council of the United States, Washington, September 2008

Lawson S, Purushothaman R, Heacock D (2005) 60 is the new 55: how the 66 can mitigate the burden of aging. Goldman Sachs Global Economic Paper No. 132, 28 September. Available at http://www2.goldmansachs.com/ideas/demographic-change/60-is-the-new-55-pdf.pdf

Lenton R, Wright AM, Lewis L (2005) Health, dignity and development: what will it take? UN millennium development project task force on water and sanitation, Earthscan, London

Marañón-Pimentel B (2009) Economic and health costs related to the lack of reliable drinking water supply services in Mexico City. Int J Water Resour Dev 25(1):65–80, March

Munich Re Foundation (2007) Report, from knowledge to action, Munich

National Research Council of the National Academies (2008) Water implications of biofuels production in the United States, The National Academy Press,Washington, DC National Academy of Sciences, 2008

NETL (2006) Water & energy. Addressing the critical link between the nation's water resources and reliable and secure energy. US Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory, Albany

NETL (2008) Estimating freshwater needs to meet future thermoelectric generation requirements, 2008 Update. DOE/NETL-400/2008/1339, National Energy Technology Laboratory, Department of Energy, United States of America, Albany

NIC (2008) Global Trends 2025: A Transformed World, National Intelligence Council, Government of the United States, Washington, p. 52

OECD (2007) Environmental Outlook to 2030. Organisation for Economic Co-operation and Development, Paris

OECD (2008) OECD Forum 2008 "Climate change, growth, stability", policy brief, special edition, OECD, Paris

OECD/IEA (2008) Key World Energy Statistics, Organisation for Economic Co-operation and Development and International Energy Agency, Paris

Rangachari R (2006) Bhakra-Nangal project, socio-economic and environmental impacts. Oxford University Press, New Delhi

Tortajada C (2004) South-eastern anatolia project: Impacts of the Ataturk Dam. In: Biswas AK, Unver O, Tortajada C (eds) Water as a focus for regional development. Oxford University Press, Delhi, pp. 190–250

Tortajada C (2008a) Challenges and realities of water management of megacities: the case of Mexico City metropolitan area. J Int Aff (Spring) 61(2):147–166

Tortajada C (2008b) Rethinking water governance. In: Feyen J, Shannon K, Neveille M (eds) Water and urban development paradigms. Towards an integration of engineering, design and management approaches, CRC Press, London, pp. 523–541

United Nations, Department of Economic and Social Affairs, Population Division (2007a) World population prospects: The 2006 Revision, Highlights, Working Paper No. ESA/P/WP.202, New York

United Nations, Department of Economic and Social Affairs, Population Division (2007b) World Population Ageing, New York

Varis O (2009) More urban and more aged: demographic pressures to global water resources by 2050. In: Biswas AK, Tortajada C, Izquierdo R (eds) Water management beyond 2020. Springer, Berlin

Wilson D, Dragusanu R (2008) The Expanding Middle: The Exploding World Middle Class and Falling Global Inequality, Goldman Sachs, Global Economic Paper No. 170, New York, July 7, 2008