View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by OpenSIUC

WATER AND THE CHALLENGE OF LINKED ENVIRONMENTAL CHANGES

Richard H. Moss
Battelle Pacific Northwest National Laboratory
Head, IPCC WorkGroup II, Technical Support Unit

INTRODUCTION

Water is essential and precious, yet often undervalued and wasted. Its abundance and our long experience with managing its fluctuations can make us complacent about our ability to meet demands for this critical resource in the future. Do current and potential future conditions support the conclusion that water will be available in the quantities and quality needed for human development? This introduction raises some questions about current conditions and future projections for water resources management. It lays down a challenge to those currently engaged in managing water resources: to explore the combinations of conditions and changes that would lead to potential problems for water supply systems in the future. The point of such an exploration is not to dream up problems where none may exist. Rather it is to prepare for potential surprises resulting from the interaction of population growth, increasing water use per capita, and environmental changes including climate change, land-use change (including deforestation and loss of wetlands), land degradation, introduction of persistent organic pollutants, and loss of biodiversity. Given the stakes - continued adequate water supplies in some regions, and improvement to minimum standards in others - there is value in the mental exercise of challenging our assumptions that incremental changes in current practices will enable us to cope with the range of demand and supply changes that we may encounter in the future.

THE CHALLENGES OF TODAY

Freshwater supplies are limited by the rate of the hydrological cycle, since they are created when sea water evaporates and falls onto the Earth’s terrestrial surface as precipitation. This precipitation is absorbed into the ground, where it provides moisture for plants and recharges aquifers; runs off into surface bodies of water, including rivers, lakes, streams, and wetlands; or is stored as ice in glaciers and snow. Fresh water can be reused many times - for drinking, cooking, cleaning, growing food, recreation, and disposal of wastes - depending on how it is managed.

In places where poverty is not a major problem, water is made available to human populations on a reliable basis by controlling and channeling water supplies. Elaborate inter-connected systems of dikes, levees, canals, and reservoirs can store water when and where it is abundant and move it to other locations, to ensure availability in times and places that it is in short supply. This does not mean that relatively wealthy populations do not face water resources-related challenges. Even in these countries, migration and population growth are straining water resources in some regions. In the United States, for example, a number of locations (e.g., California and regions drawing on the Ogalala aquifer) are facing supply shortages due to continued agricultural uses and increasing demands for household and industrial use. Water quality problems abound even in regions where supply is not a problem. The U.S. Army Corps of Engineers reports that there are multiple indicators of poor water quality in many reservoirs and other water bodies in the United States. In some areas (e.g., Lower Mississippi Valley Division), nearly all reservoirs show contaminants in fish flesh (it is not uncommon for one sample to show traces of three or four different pesticides), indicating significant concentrations of metals and other toxics in the water. Urbanization clearly is resulting in serious impacts to reservoir systems, especially sedimentation associated with construction activities.

Unfortunately, the situation in regions where most people live in poverty is much worse. It has been estimated that more than one billion people do not have access to reliable supplies of safe water for domestic uses.

Although these people are dispersed throughout the globe - reflecting sub-national variations in water availability and quality - the most severe water supply and quality problems often are found in developing countries. Examples of unsustainable water uses in these regions include over-pumping of aquifers (e.g., North Africa, the Middle East, India, and Southeast Asia), and diversion of river water leading to depletion of wetlands and lakes (e.g., Aral Sea) and intrusion of sea water into deltas and coastal aquifers (e.g., China, Vietnam, Bangladesh). Because of the lack of adequate sanitation facilities in many of these same locations, people often withdraw water for consumption from the same water bodies into which human, agricultural, and industrial wastes flow, leading to a widespread incidence of water-borne illnesses such as diarrhea.

LINKED DEMOGRAPHIC, ECONOMIC, AND ENVIRONMENTAL TRENDS: SCENARIOS FOR THE FUTURE

No one can say with any certainty whether water resources will be available in adequate quantity and quality in the future. It is within our influence, however, to help steer the situation in a positive direction. Certainly broad forces such as population growth - an issue with ramifications far broader than its impact on water supply - will affect the availability of water resources in a number of ways, such as increasing demand and increasing population density in major watersheds. These factors are important to consider but, in the context of water resources management, they are difficult to steer. Other factors, however, such as water-use policies and the design and maintenance of infrastructures, are more directly under the control of water resource managers and planners; it is thus helpful to examine the sensitivity of water supply and demand to such factors under potential future conditions.

Due to the imprecision of quantitative predictions about future conditions, it is useful to examine potential future challenges for the water resources sector through the analysis of several different scenarios. These scenarios should not attempt to constitute a single, "best guess" forecast of future conditions, but rather should explore different trajectories and sets of choices that could lead to varying conditions, reflecting the divergent starting points for water resources management in different sectors and regions around the globe. Scenarios are an important tool because they can help us to conceive of some of the choices that may shape future conditions, and to explore the implications of different strategies for managing water resources.

These scenarios should be based on an assessment of the critical trends that will matter most in shaping future supply and demand for water resources. The remainder of this introduction will review an initial list of the trends that could most affect water resources management and that should thus be factored into the scenarios.

Population

Population growth could affect water resources by increasing demands for water as well as by altering conditions that influence the quantity and quality of water supplies; for example, land clearance practices, intensity of agriculture, and density of settlement in watersheds all affect sedimentation and reservoir capacity. A number of studies have calculated the effects of population growth on water resources, holding water resources constant - a potentially questionable assumption. Based on United Nations population projections, the number of people living in "water-scarce" countries (those where water availability falls below 1,000 cubic meters per capita per year) could rise from 132 million in 1990 to between 650 million and 900 million in 2025, and to approximately 1-2.5 billion (roughly 13-20 percent of the projected global population) by 2050. A challenge for future analysts will be to develop improved projections of the effects of population growth not only on water demands, but also on those factors that will affect water supply and quality.

Land-Use Change, Including Deforestation and Loss of Wetlands

Ecosystems, particularly forests, are being cleared and degraded at rapid rates in many parts of the world, resulting in changes dramatic enough to be seen easily in satellite images. One recent study estimates that only one fifth of the world's original forests remain in a natural state. Conversion of forests to agricultural systems or suburban or urban environments reduces the land's ability to absorb and hold precipitation. Converted areas can become more prone to flooding during rainy seasons because of increased rates of runoff, and more vulnerable to water scarcity during dry periods. Deforestation and other types of land conversion also increase rates of soil erosion, which contributes to sedimentation of reservoirs and leads to decreased water storage capacity. Wetlands, which serve several important hydrological functions - including absorbing pollutants and wastes from runoff, stabilizing soils, and preventing massive runoff during floods - also are undergoing rapid conversion. It has been estimated that more than half of the world's wetlands have disappeared since 1900, and that this trend will increase, especially in developing countries, due to agricultural development. The overall effect on water resources will depend on how land-use patterns change in the future, and how these changes affect the ability of human management regimes to work in harmony with natural processes to provide adequate supplies of high quality water for human uses.

Land Degradation

Roughly one fourth of the Earth's land surface is used for production of food. As use of these lands has intensified in order to increase production per unit of land, land degradation has become an increasingly serious problem, particularly where poor land management practices have been followed. It is estimated that erosion, salinization, compaction, and other forms of degradation affect 30 percent of irrigated lands and an even higher percentage of rainfed agricultural lands. These problems often are accompanied by reduced water infiltration and increased soil erosion. These conditions not only reduce agricultural productivity, but also lead to increased pollution of surface waters as a result of both increased runoff of fertilizers and sediment loading of streams, rivers, lakes, and reservoirs. A key question for the future is the extent to which land degradation will accelerate or abate, and how it will affect water quality and the condition of water management systems.

Climate Change

Much has been written recently about changes in the Earth's climate resulting from human activities, particularly the burning of fossil fuels. The climate already has warmed by about half a degree Centigrade this century, and is projected to warm another 1.0-3.5 degrees C over the next century, assuming continued increases in atmospheric concentrations of greenhouse gases. These changes are projected to result in changes in the overall amount, frequency, intensity, and perhaps variability of precipitation around the world. While projections of regional effects are uncertain, all global climate models show a tendency to mid-continental warming and drying resulting from increased temperatures and evapotranspiration. Changes in the hydrological cycle would likely affect both water supply and demand as well as water quality, presenting water resources managers with a need to reexamine design criteria, operating rules, and water allocation policies. A further challenge will be to anticipate the potential interactions of climate change with other environmental trends, such as increased water pollutant loads resulting from urbanization and industrial development.

Urbanization and Industrial Development

Since 1950, the number of people living in cities has tripled - by 1990, it was estimated that nearly 43 percent of the world's population lived in cities, and this number could rise to 60 percent by 2025. Much of this growth has occurred in very large cities in developing countries, where infrastructure for handling human and industrial wastes is lacking. Indeed, water pollution from industrial, municipal, and agricultural sources presents an extremely serious hazard to future water quality. Progress in controlling these pollution sources has been made in many developed nations over the past three decades, but pollution problems are intensifying in most developing nations and remain high in the transition economies of Russia and central Europe. Pollution control in many human settlements in these regions is still rudimentary or nonexistent: domestic sewage and industrial effluents often are left to drain into urban rivers and groundwater sources, making it more difficult to provide clean water and basic sanitation services. Some of the pollutants (e.g., dioxins, PCBs, and others) released from industries in these burgeoning cities, or used as pesticides in applications both within and outside urban areas, have chemical structures that allow them to persist in the environment, resisting natural degradation. These can be carried in wastewater into lakes and reservoirs, where their concentrations increase - eventually accumulating in the fatty tissues of a wide range of organisms, including humans. Some of these compounds have been shown to cause cancers and birth defects. It is unknown to what extent pollution problems will worsen and increase the technical challenges and economic costs of purifying fresh water for human consumption.

Ecosystem Preservation

Because humans appropriate only a fraction of globally-available water resources for their own direct use, it frequently is assumed that the remaining water will be more than adequate to maintain natural ecosystems, including aquatic systems. In many regions, however, this is no longer the case, as increasing percentages of surface waters are diverted for human uses. In some regions, such as south Florida, ecosystem maintenance competes directly for water with other uses such as agriculture. Even in areas where quantity of water is not a problem for maintenance of ecosystems, water quality is being seriously affected. Runoff from the application of agricultural chemicals and increasing concentrations of untreated sewage and other pollutants are causing die-off of aquatic organisms, due to reduced dissolved oxygen content and/or the spread of bacteria or other pathogens that attack the endemic species. Biodiversity in freshwater systems is particularly threatened by these trends because freshwater habitats are discontinuous and separated by land barriers that make migration to new habitats difficult. A key issue for water resources management is the extent to which it will be possible to anticipate "ecosystem needs" for fresh water and make the tradeoffs with human consumption without disrupting either ecological or social/economic systems.

Policies and Measures

In many countries, the policies (e.g., taxes, subsidies, and regulations) that shape private decision making, development strategies, and resource-use patterns (and hence environmental conditions) hinder improved management of water resources. Although increases in water-use efficiency have been demonstrated in both agriculture and industry, the failure to adopt and implement more efficient water management practices often can be traced back to water management policies, particularly the underpricing of water. Direct and indirect subsidies, especially for agricultural use, encourage the overuse of water and its diversion away from higher value domestic or industrial uses. Administrative or market mechanisms can provide incentives for efficient use and can help finance the needed infrastructure to expand services to new users. Important questions include the extent to which the policy and regulatory context of water resources management has been improved, and how these improvements will affect the condition of infrastructure and management capability in the next 10-20 years.

CONCLUSIONS

Meeting the challenges of the next century will require water managers to think more creatively about the potential to manage water demands and supplies, and to look for opportunities for improving water management systems that also have benefits in other economic sectors or to the environment. In light of both environmental and fiscal/technical constraints, water managers will need to think beyond traditional instruments (e.g., changes to management of existing infrastructure, new infrastructure, and promoting changes in water use patterns), although these will be important tools. They will need to design ways to integrate their work with that of resources managers in other sectors, including agriculture, forestry, ecological conservation, industry, and energy. Developing approaches that build on these links and minimize the inherent tradeoffs among these issues is a growing challenge for water management and policy development.

Richard Moss currently heads the Technical Support Unit for the Intergovernmental Panel on Climate Change (IPCC), Working Group II. In this capacity, he serves as lead author or coordinator of a number of IPCC technical papers and special reports on subjects related to assessment of potential climate-change impacts or mitigation strategies. He co-edited *Climate Change 1995: Impacts, Adaptation, and Mitigation*, one of the three volumes of the IPCC's Second Assessment Report, which was published by Cambridge University Press, and has written a number of other articles and scholarly publications on global change. Before taking up his current position, Richard served as programme officer of the International Geosphere-Biosphere Programme (IGBP) and Human Dimensions Programme (HDP) in Stockholm, Sweden, where he edited an IGBP-HDP research report on land use and land-cover change and worked toward establishment of an IGBP-HDP core research project on this topic. He was also on the faculty of Princeton University from 1989-1991, where he served as lecturer at the Woodrow Wilson School of Public and International Affairs. In 1991, he received a two-year Council on Foreign Relations (NY) *International Affairs Fellowship* for work on international aspects of global change. Richard received his B.A. in 1977 from Carleton College, Northfield, MN (Magna cum Laude, Phi Beta Kappa); he earned his MPA in 1983 from Princeton University, (University Fellowship), and he received his Ph.D. from Princeton University, Woodrow Wilson School of Public and International Affairs (University Fellowship) in 1987.