Chapter 4

Water Management in 2050

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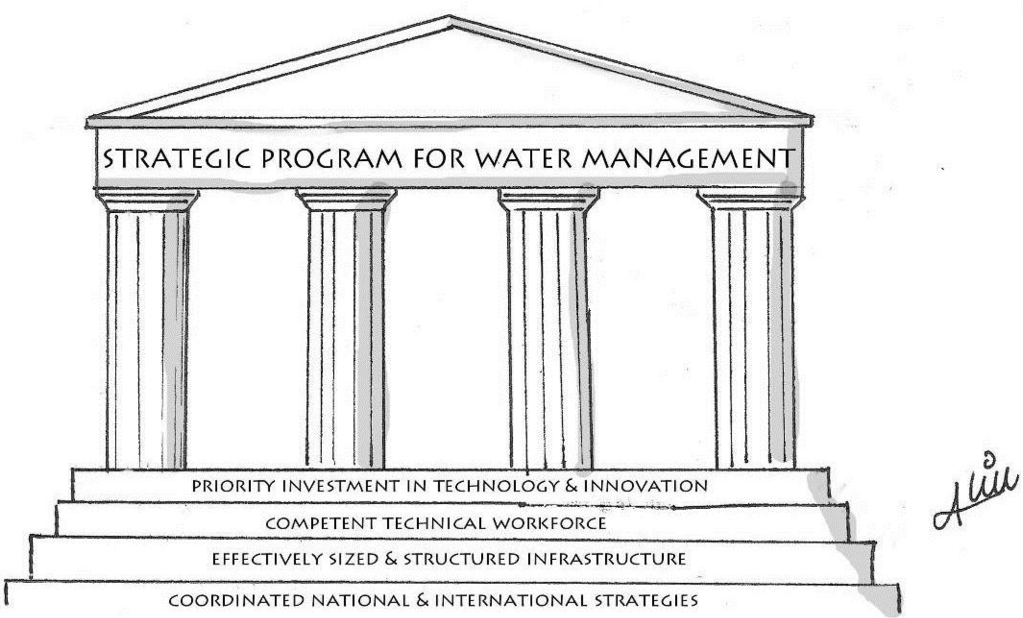
ABSTRACT

Local, national, and international water resources management encompasses a broad range of activities from flood control to providing adequate supplies of clean water for domestic use. As populations shift and expand, it will become increasingly difficult to meet consumer demands for reliable water of high quality. Future flood damages, already nature's greatest source of destruction, will likely become even greater as riparian populations increase and property values rise. The focus of this chapter is on *timely adaptation* to change. The water management tools for this approach are policies, means and actions. Ideally water systems planning, design and operations should evolve to rely more on science and technology and less on arbitrary political decisions. Realistically, the challenge for adaptation is to recognize changes in advance and to appropriately modify or invent new technologies, rules, regulations, and institutional and political arrangements. The perspective of this chapter is that of developed countries with the hope that, with proper commitment, improvements to water management practices wherever made will also find their way to less developed countries.



INTRODUCTION

Water resources management has a long history of notable water engineering achievements. Among the most famous are Hezekiah's tunnel that delivered water to Jerusalem, the qanats of Persia, aqueducts of Rome, and the Grand Canal and the Dujiangyuan River diversion in China. These major projects are lasting symbols of the planning and engineering organizations that identified the opportunities and funding, undertook the surveys, developed designs, assembled the contractors, supervised construction, and managed financing and operation of the facilities. Since 1850 the US government has responded to problems by passing several national water planning acts and initiatives to modify policies and plans for management of irrigation, water quality, hydroelectric power, navigation, and flood control. Other nations and international political alliances have followed similar paths (e.g., Australian Government National Water Commission (2009), European Union Water Framework Directive (2000)). There can be no doubt that underlying issues of water management will continue to evolve to 2050 and beyond, accentuated by the expansion of populations and changes in the availability of water.

As competition for water grows and floodplains became more densely populated, especially in urban areas, water management will become more difficult and complex. Physical and institutional challenges to serve and protect consumer sectors will stem from a variety of reasons:

- declining availability of good quality natural water;
- higher variability of supplies driven by climate change;
- rising costs of securing water quality;
- population pressures;
- affordable potable water treatment for developing countries;
- sustaining agriculture and the public services it provides;
- increasing public demand to sustain and protect the environment with its diverse ecology and ever-expanding services;
- continuous evolution of technology; and
- evolution of national and international structures, laws and regulations.

Much can and must be done through supply side management by developing new infrastructure and through watershed protection to *mitigate* diminishing access to supplies, declining water quality, and the increasing threats of flood damage. *Mitigating* change offers possibilities, for example by reducing pollution of sources, but introduces heightened uncertainties and high costs. A better approach is *adaptation* to change through demand side management. Demand side management emphasizes priorities on robust planning to *adapt* water management to the expected changes in supplies. While both supply and demand side management offer possible solutions on their own, policies and actions with a rational balance of supply and demand are the most effective way to achieve safety and reliability of water services.

The lack of coincidence between political and physical water boundaries generates difficulties in rational management. Difficulties arise through incomplete scientific information, real or seemingly conflicting objectives (e.g., local economic development versus national environmental quality), and political mandates. The greatest obstacle to rational management of water stems today from the lack of cooperative agreements among political jurisdictions.

Water resources and water control systems are managed over a range of political levels: local, urban, national, regional, and international. Within each level and in coordination with the other levels, decisions depend on the issues being addressed and the specific interacting political and institutional systems. The pressures of scarcity and the threats of future flood damage create incentives for cooperative actions to overcome political/institutional/legal constraints on effective physical and economical management of water resources.

: The greatest obstacle to rational management of water stems from failures of governance and lack of coordination among political jurisdictions.

Modalities for water management vary widely among countries, but universal key priorities are to avoid over-exploitation and pollution of natural sources and to provide flood management. In the developing world, water management is far from maturity, whereas in the developed world it is more sophisticated but still less than perfect. The 3rd World Water Development Report provides, through its chapters and case studies, a water management panorama with considerable emphasis on developing countries (WWAP2009, see especially Part 4: Responses and choices).

FUTURE TECHNOLOGIES FOR ADAPTING TO CHANGE

Monitoring: Before water can be managed, it must be known in quality and quantity with methods for predicting its future behavior in time and space. The 21st century is a breakthrough century for remote sensing, distributed monitoring and control of water facilities. Remote sensing technologies provide diagnostic measurements as a means for compensating for the reduction in land-based monitoring systems, and for expanding into data sparse regions, in particular in the developing world. These techniques are already being used on local to continental scales to detect changes in soil moisture and water stored in changing levels of snow, rivers and lakes.(Committee on Earth Science and Applications from Space 2007). New sensors and algorithms will extend these measurements to estimate river discharges and to predict drought. Improved near-real-time estimates of precipitation will be available widely for any location on earth. In the next few years these technologies will be perfected to provide more accurate and more frequent updates of data for controlling facilities that manage floods and distribute water to fields and to cities.

Reduction of water losses: Benefits of improved water management based on better data will include reduced evaporation losses from reservoirs, reduced leakage from distribution systems, and improved management of surface and groundwater reservoirs.

Reduced water use in home and city without lowering the quality-of-life: Modern household laundry machines already use 40% less water and less energy than machines of only a few years ago (Consumer Reports, 2010). Technology advances will provide on-site disposal of human and household waste with little or no water usage. Many household appliances will use less water or none at all. Recycled water for special uses will become more widely used and accepted and localized treatment will become a viable option to the costs and waste of centralized water pumping and transport. Sewerage systems and wastewater treatment plants will be upgraded to accommodate lower flows, higher concentrations and a wider range of pollutants.

Efficient irrigation technologies: Optimized application of irrigation will continue to develop with new sensors and remotely sensed monitoring of site specific plant stress in agriculture, parks and gardens. Precision and automated agricultural practices based on local feedback systems and space platforms will significantly reduce water use in the industry that is the largest consumer of water world wide. (Committee on Earth Science and Applications from Space 2007).

Stress resistant crops and plants: Widespread planting of engineered species will generate the same or better crops with lower quantity and lesser quality of water.

Systems approach to integrated uses and non-potable water treatment: Systems will include desalination of sea-water and brackish groundwater, treatment of sewage for irrigation and domestic use, and new molecular separation and membrane technologies for removal of trace pollutants. Design improvements for parallel multi-quality and blended-quality supply systems will increase the flexibility of developing and operating distribution networks.

Targeted water treatment for natural, recycled and manufactured water: Treatment and transport systems will produce and deliver customized product streams that meet quality requirements for specific uses.

Point-of-Use (POU) water treatment technologies: While public urban water supply systems must be obligated to deliver potable water quality, there are opportunities and good reasons to advance in parallel with POU technologies. These range from simple and cheap devices suitable for rural and urban communities in developing countries (Clearinghouse 2009; Doocy and Burnham 2006; NSF International 2009) to reverse osmosis and ultraviolet-based systems that can be used in homes, public buildings, restaurants and mass feeding establishments. For example, Life Straw is a simple hand-held filter device that can filter up to 700 liters of water to remove dirt and kill bacteria, viruses and parasitic organisms ($3-5/unit), and ceramic filters (from 1-10 liter/hr, useful life 6 months to 10 years, $2.25-3.50/unit) can remove biological contaminants. POU can improve public health in poor communities, address accidental or intentional contamination events in distribution systems, and reduce the serious negative environmental consequences of bottled water. There is great potential for POU innovations, including low-cost devices and innovative use of nanotechnology materials.

Water Sensitive Planning (WSP) of the built environment: Water considerations will be integrated into planning and maintenance of land uses and land cover at all spatial levels from yard and neighborhood to the entire watershed. Such initiatives will minimize the loss of useful runoff water, reduce flooding, improve streamflow regimes, reduce downstream pollution and enhance the environment by judicious placement of built and open spaces, landscaping, and use of best management practices for infiltration of runoff and regulation of flows (Carmon and Shamir 2010; USEPA 2007).

Watershed management: Planning and operation of water supply, water quality and flood protection schemes will be based on a watershed framework, the natural and necessary unit for rational water management.

Models and systems to support decision making: Improved models will be developed for supply and flood forecasting and for chemistry and biology in rivers, water bodies, groundwater, wetlands and other ecological systems. Efficient and effective optimization methods will support management decisions that face uncertainties.

Methodologies for formulation of water management policies, strategies and master plans, comprising: (1) definition of the physical, organizational and institutional water system and its division into logical subsystems; (2) identification of the boundaries with other systems, and the "boundary conditions;" (3) identification of the system's objectives, and their organization into a hierarchy; (4) definition of the measures by which the attainment of these objectives is to be evaluated; (5) identification of all policy areas, and for each of its components; (6) identification of all "reasonable" alternatives for each component; (7) identification and analysis of the effects of each alternative on all measures; (8) construction of candidate comprehensive policies, for one policy area, for a group of areas, or for all of the areas, by selecting one alternative for each component; (9) evaluation of these policies according to their effects on the measures, and thus on the objectives, using multi-objective evaluation methods; (10) interaction with decision-makers, interest groups, and experts throughout the above activities to aid in decision-making; (11) continuous monitoring and evaluation of changing conditions and of the effectiveness of implemented policies that are reported to the decision-makers and that provide feedback on all phases of the analysis. This approach has been applied in the past (Shamir et al. 1985) and is currently being used for the Israeli Water Sector.

WATER ECONOMICS

Pricing alone pays for water but does not capture its value. The value of water has three components (Howard 2003): (1) Existence value; (2) Aesthetic and environmental value; and (3) Economic value. Water provides common goods that are difficult to measure. Water management must also maintain equity among users and can be a motive for political agreement. For sustainable water infrastructure and rational management, it is necessary for social policy adjustments to support cost-based pricing for all sectors.

Water supplies, like other commodities, only have economic value in relation to their scarcity. Thus, the value of water is related to the reliability of its supply. Also, like some other resources, the value stems from water's role in the production of other goods and services. As a result, estimates of the economic value of water, and its pricing, must include measures of both its reliability and its impact on economic and social activity.

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Demand management and temporary curtailment of water supplies during drought have an effect that is much broader than water pricing. They affect the regional economy and imply the use of devices and operating strategies that affect one or more parameters of the criteria for management of supply systems. Together the intersection of water supply and demand define the reliability of a system and managers must be skilled in both. Engineers will become participants and partners with politicians and citizens in the process of effective and equitable balancing of both aspects to develop appropriate water supply management criteria.

INSTITUTIONAL, POLITICAL AND INTERNATIONAL ARRANGEMENTS

Politicians view water as a strategic resource, a life-giving element that cannot be given up or even shared. But while water is essential to support life (its "existence value") it also has aesthetic, environmental and economic values that are created jointly with other inputs, including land, labor, technologies, and investments. Even the "existence value" of water should be placed in an economic context because where supply can be augmented, the value of water cannot be greater than the cost of producing it (Fisher et al. 2005).

A paradigm shift will be required to move policies, agreements and plans from simply *allocation* of water to *sharing its benefits* in combination with other inputs. Benefits can be focused to represent the parties' priorities and preferences (Fisher et al. 2005; Jenkins et al. 2004; Kronaveter and Shamir 2009a,b).

The share of water supplies and services by public-private partnerships has risen dramatically over the last few of decades. Past successes and failures indicate that with a degree of caution, and without the state relinquishing its overall responsibility, the relative advantages of the public and private sectors can be combined to create a more effective water management framework. Public-civic partnerships, with civil society mobilized to participate more fully in policy and management decisions, are also gaining an increasing role in water management. Civil society's involvement is essential for successful demand management, and acceptance during droughtof temporary curtailment of consumption.

International coordinated or cooperative water management of shared water resources can yield substantial benefits (Kronaveter and Shamir 2009a,b). Contrary to some publicized statements that "water will be the cause of future wars," there is ample evidence of cooperation among neighboring countries and of stable water agreements that survive even in times of political strain and conflict (Wolf 2007). Because water has values beyond its "existence value," it is possible to base international arrangements on sharing the benefits created by water rather than sharing water itself.

SUMMARY

As water issues become more pressing, merely waiting and expecting that progress is inevitable will not serve society. Improvements in water management will come through innovation fueled by individual curiosity, dedicated effort, and opportunities within a strategic program supported by national and international agencies, universities and industries.

Four foundational elements are critical to a purposeful, effective, strategic program for advancement in water management, science and engineering:

1. *Coordinated national and international strategies* - implementing national water policy coherently across all agencies in support of national needs and priorities while paying attention to regional and international shared interests for efficient management of water resources;
2. *A competent technical workforce* - developing expertise sufficient in numbers, talent, breadth of perspective and experience to address difficult and pressing challenges;
3. *An effectively sized and structured infrastructure* - realizing synergy from the public and private sectors and from international partnerships – commitment to infrastructure for water on a scale like preparing to host an Olympics; and
4. *A priority investment in technology and innovation* - strengthening and sustaining capacity to meet national and international needs through major support for research that can provide transformational advances.

This century continues to present age-old water management problems in unpalatable packages of population pressure, political changes and the uncertainties of climate change. A well-defined broad path for future investment in water science and technology will present unparalleled opportunities for advancing the quality of life throughout the world.

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