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**Law for water
management: a guide to
concepts and effective
approaches**



Law for water management: a guide to concepts and effective approaches

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for the
Development Law Service
FAO Legal Office

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ABBREVIATIONS

BAT	Best Available Technology
BATNEEC	Best Available Technology Not Entailing Excessive Cost
BEP	Best Environmental Practices
BMP	Best Management Practices
BOD	Biological Oxygen
BOT	Build-Operate-Transfer
CESCR	United Nations Committee on Economic, Social and Cultural Rights
CRP	Conservation Reserve Program (United States)
DNR	Department of Natural Resources (Indiana, United States)
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
FAO	Food and Agriculture Organization of the United Nations
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
HIA	Health Impact Assessment
ICESCR	International Covenant on Economic, Social and Cultural Rights
ICJ	International Court of Justice
ILA	International Law Association
ILC	International Law Commission of the United Nations
IRPTC	International Register of Potentially Toxic Chemicals
IWRM	Integrated Water Resource Management
JMP	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation
LVFO	Lake Victoria Fisheries Organization
M&I	Municipal and Industrial
MDGs	Millennium Development Goals
NGO	Non-Governmental Organization
NEPA	National Environmental Policy Act (United States)
NWI	National Water Initiative (Australia)

OECD	Organisation for Economic Co-operation and Development
OKACOM	Permanent Okavango River Basin Water Commission
PCB	Polychlorinated Biphenyl
POP	Persistent Organic Pollutant
POTW	Publicly Owned Treatment Works
SFRA	Stream Flow Reduction Activity
TMDL	Total Maximum Daily Load
TSA	Trail Smelter Arbitration
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGA	United Nations General Assembly
UNICEF	United Nations Children's Fund
UWWT	European Council Directive Concerning Urban Waste Water Treatment
WHO	World Health Organization
WPWP	Working Party on Water Problems (Helsinki Convention)
WQS	Water Quality Standards
WSP	Water Safety Plan
WSRA	Wild and Scenic Rivers Act (United States)
WTO	World Trade Organization
WUA	Water Users' Association
WWAP	United Nations World Water Assessment Programme

GLOSSARY*

aquifer: a geological area that produces a quantity of water from permeable rock.

annual water yield: the total volume of water produced by a watershed on an annual basis.

appurtenant: belonging or attached to; constituting a legal accompaniment.

atmospheric deposition: the processes, excluding precipitation, by which materials are removed from the atmosphere and deposited on the surface of the earth.

baseflow: the sustained or dry weather flow of a stream resulting from the outflow of permanent or perched groundwater and from the drainage of lakes and swamps during dry weather; also included are water from glaciers, snow and other sources not resulting from direct runoff.

bioaccumulate: the process by which an organism absorbs a toxic substance at a rate greater than that at which the substance is lost.

blue water: freshwater found in river basins, lakes and aquifers.

cap and trade system: a system that sets an aggregate rather than individual cap on pollution (or resource use), issues individual emission (or use) permits matched by an equivalent number of allowances or credits and then allows the trading of individual credits in an amount equal to or less than the permits held.

catchment (watershed): a discrete area of land with a common drainage system; includes both the water bodies that convey the water and the land surface from which water drains into those bodies.

club good: an excludable, non-rival good or resource, or a resource to which access may be limited and the use of which does not generate competition.

* This glossary was prepared by Julia Rogers.

command and control regulations: regulations that establish the type or amount of permissible resource use, or require that certain technologies be employed for such use.

common pool resource: a non-excludable, rival resource subject to congestion or overuse.

concession contract: an agreement between a government and a private company granting the latter the exclusive right (and sometimes obligation) to operate, maintain and invest in a public utility for a given number of years.

conjunctive management: the joint or coordinated management of surface water and groundwater, in particular regarding the inflow and reservoir functions of aquifers, for the sustainable extraction of groundwater.

connectivity: the physical connection between tributaries and rivers; surface water and groundwater; and wetlands and both surface water and groundwater.

consumptive water use: water that evaporates or transpires, or is incorporated into a product or a crop, consumed by humans or animals or otherwise removed from the immediate environment.

customary international law: rules of law derived from the consistent conduct of states acting out of the belief that the law requires them to act that way; a general, international practice accepted as law.

diversion weir: a barrier or dam constructed on the reaches of a canal or navigable river to retain the water and regulate its flow.

drawdown: the change in head or water level relative to background conditions.

ecosystem: a system of dynamic interdependent relationships among living organisms and their physical environment; a bounded entity that has evolved to contain self-stabilizing mechanisms and an internal equilibrium.

ecosystem water: the water that is made available naturally by the water cycle and freshwater ecosystems.

effluent: liquid waste, whether treated or untreated, that flows from a process or facility into the environment.

effluent requirements: measure of the amount of waste material that may be discharged into the environment.

environmental flow: the amount of water needed in a watercourse to maintain healthy, natural ecosystems.

ephemeral stream: a stream that exists only in periods of heavy rainfall.

equitable utilization: the principle that each state within an international drainage basin has the right to a reasonable and equitable share in the beneficial use of the basin waters.

eutrophication: the enhancement of the natural process of biological production in rivers, lakes and reservoirs caused by an increase in the level of nutrients, usually phosphorus and nitrogen compounds.

evapotranspiration: the sum of water moving through physical evaporation and plant transpiration from the earth's surface to the atmosphere.

flood flow: see stormflow response.

fossil groundwater: water stored over geologic time in aquifers located at great depths with little or no connection to groundwater recharge; once extracted, these groundwater reserves are difficult to replenish.

freshwater in transit: freshwater molecules moving actively through the water cycle.

fund pollutants: pollutants that decompose and are therefore more readily assimilated by the environment.

general principle of international law: a principle common to the domestic laws of many nations which, because of its broad acceptance, may be considered a part of international law when neither customary nor conventional laws cover a particular legal issue.

green water: water that moves through evapotranspiration, cycling largely through plants.

groundwater discharge: outward flow of groundwater into surface waters.

groundwater recharge: replenishment of groundwater supply in the saturated zone, or addition of water to groundwater storage by natural processes or artificial methods for subsequent withdrawal for beneficial use or to check saltwater intrusion in coastal areas.

halophyte: a plant that naturally grows in locations where it is affected by salinity in the root area or by salt spray, such as in saline semi-deserts, mangrove swamps, marshes and sloughs and seashores.

headgate: a barrier that controls the flow of water into a channel.

helminth: a worm, either parasitic or free-living.

hydrograph: a record of the discharge of a water body over time.

hydrosphere: the combined mass of water found on, under and over the surface of the earth.

improved water source: a source with some form of improvement on, or protection from, groundwater, such as household connections, public standpipes, boreholes, protected dug wells, protected springs or rainwater collection.

infiltration: precipitation that enters the ground and goes into the water table.

leachate: liquid that drains from a landfill, usually composed of both dissolved and suspended waste materials.

lease affermage: a lease that gives a company the right to operate and maintain a public utility whilst investment in the utility remains a public responsibility.

macrophyte: an aquatic plant that grows in or near water and is either emergent, submergent or floating.

Millennium Development Goals: eight international development goals agreed in 2000 amongst 189 United Nations member states and at least 23 international organizations, to be achieved by 2015: eradicate extreme

poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria and other diseases; ensure environmental sustainability; and develop a global partnership for development.

mine tailings: the materials left over after the process of separating the valuable fraction from the worthless fraction of an ore.

non-point source pollution: pollution from multiple or unidentified sources that is delivered to water systems through runoff, infiltration or other unchanneled means, as well as through precipitation that has bonded with pollutants in the atmosphere.

nutrient outflow: the amount of nutrients (fertilizer) flowing from an agricultural watershed into a body of water in a given amount of time.

parastatal: an organization or industry with political authority that serves a state indirectly.

perched aquifer: an aquifer that is stored above an impermeable layer and has no outlet.

point source pollution: pollution conveyed to water systems by a discrete and identifiable outlet.

prior appropriation doctrine: a system that gives the first person who makes beneficial use of a quantity of water from a given source the right to continue to use such quantity for the same purpose; subsequent users may use the remaining water for their own beneficial purposes, provided they do not impinge on the rights of the prior user(s).

public good: a non-excludable, non-rival resource.

recharge pit: a means of capturing rainwater runoff to recharge groundwater supplies; typically consists of a pit filled with stones and sand through which water percolates.

return flow: see groundwater discharge.

riparian rights: the rights of land owners to access and use the water that borders their property.

rivalry: the degree to which the use of a unit of a good by one individual reduces the potential for others to use the same unit.

run-of-river hydropower facility: a facility in which the river current applies the needed pressure to generate electricity through either a diversion or a barrage system, the former using only the force of gravity, the latter using a barrier to increase force by creating a backup of water.

saturated zone: the area below the water table where all open spaces are filled with water.

self-executing treaty: a treaty that comes into effect immediately upon ratification and does not require national implementing legislation.

soil water: water that occupies the unsaturated zone directly above the water table, rests in the spaces between particles of soil and is immediately available to plants.

static storage: water in static storage is water that does not move through the water cycle.

stock pollutants: pollutants that accumulate with little or very slow degradation because the capacity of the environment to assimilate them is very small.

stormflow response (flood flow): stream discharge during a flood.

streamflow: the flow of water in streams, rivers and other channels, and the main mechanism by which water moves from land to the oceans.

total maximum daily load: the maximum amount of pollutants a water body can receive and still meet water quality standards.

unsaturated zone: the shallow layer of earth located directly above the water table.

vadose zone: the unsaturated layer above the water table.

water abstraction: the process of taking water from any source, either temporarily or permanently.

water quality standards: benchmarks established to determine whether water quality is sufficient for certain uses; typically expressed as maximum allowable concentrations of pollutants.

watershed: see catchment.

water table: the top of the saturated zone; the depth from which water can be extracted.

water yield: total volume of water produced by a watershed on an annual basis.

wellhead: the structure built over a well to protect the water.

wetland: an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres.

PREFACE

Water is a fundamental resource for life and plays an essential role in agriculture, power generation, social development and health. Increases in human population and demographic shifts towards more urban areas have heightened demand for water, creating new challenges in managing water resources, water supply and sanitation infrastructure. Increased demand has also created conflicts over national and international water resources. The future will call for improved management of water resources to address these and other challenges.

Effective water management relies on a wide range of institutions and actors playing distinct but inter-connected roles. Coordination and cooperation are essential to ensure effective water management, health protection and sustainable development. Good water policies implemented by nationally tailored water legislation and other tools can facilitate coordination and help governments achieve their water management objectives.

Close cooperation will be needed between those with technical water expertise and those with expertise in legislation and regulation. The legal profession has a suite of tools that may provide a better or worse “fit” to a specific water management issue. The community of water managers, for its part, has a suite of technical tools that it uses to respond to regulatory challenges. Although communication between these two groups is vital in order to assess potential design and implementation issues, it is often constrained by different perspectives and vocabularies. A common lack of understanding can impede innovation and identification of the most effective solutions to water management problems.

This text was conceived by staff of FAO and WHO as a resource to bridge the gap between these disparate groups. It is intended to support legal experts, policy experts and other interested individuals in understanding the scientific and technical issues associated with water, health and development, whilst raising awareness on the part of scientists and technical experts regarding the legal and policy issues surrounding water management.

FAO and WHO address water-related issues according to their respective mandates and perspectives. FAO, in its role as an advisor to governments and neutral forum for inter-governmental consultations on issues of food and agriculture, is concerned with water as a resource and as an integral

element of sustainable agriculture and rural development. WHO, on the other hand, was created for the purpose of ensuring health for all people and, accordingly, approaches water from a global health perspective. Marrying these two important objectives will be an important step toward improving water management practices.

The complexity of the task has meant a lengthy and sustained effort on the part of many people in FAO, WHO and elsewhere. Jessica Vapnek, FAO Legal Officer, and Jamie Bartram, formerly Coordinator of the Water, Sanitation and Health Programme at WHO, conceived the text and its companion website, www.waterlawandstandards.org, and led the editing of the text. Bruce Aylward and Christie Popp completed the editorial team. Many other people have participated in aspects of this project, and the editorial team would like especially to thank Bo Appelgren, Jeremy Bird, Robert Bos, Jake Burke, Rich Carr, David Coates, Ariella D'Andrea, Susan Davis, Megan Dyson, Maj Fiil, Jared Gardner, Hiroki Hashizume, Federike Jansonius, Charlotta Jull, Donald Kaniaru, Rachael Knight, Julia Lenney, Meg Mahoney, Kerstin Mechlem, Jennifer Mercer, Deana Nassar, Jane O'Farrell, David Percy, Claudia Sadoff, Jim Salzman, Jackie Sims and Melvin Spreij. These many individuals provided administrative, editorial or research support, or offered expert reviews of draft chapters. The project could not have been completed without them.

The books' authors represent or represented FAO, WHO, universities, government agencies, NGOs and the private sector. The views expressed in the various chapters are personal to the authors and do not necessarily represent those of their respective organizations.

We hope that this text will prove useful to government policy-makers, law-makers and researchers alike.

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INTRODUCTION*

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* This chapter was prepared by Bruce Aylward, Jamie Bartram and Sasha Koo-Oshima.

Ancient and fundamental, water is inextricably a part of us and one of the few essential requirements for life. From the very first settlements, the health, welfare and development of societies have been predicated on readily available, safe sources of drinking water. Scholars have found that ancient civilizations declined and at times collapsed because of misuse of water resources. Other commentators have suggested that the economic gains of the nineteenth and twentieth centuries were founded upon major advances in the provision of water. Today is no different. Water resources development has altered the natural functioning of the water cycle to better meet human needs, particularly the major human consumptive uses (irrigation, municipal and industrial) and non-consumptive uses (hydropower and navigation). Humankind's ability to re-work river systems and plumb aquifers has allowed civilization to flourish.

Water is essential to human development. Freshwater and inland water bodies underpin national economic and social development by providing essential goods and services for households and producers. The water cycle is also vital to ecosystem health, and supports not only basic human needs but also cultural uses of water including tourism and recreation. In the modern era, population growth and social and economic development have rapidly increased the demand for water and placed escalating pressures on the world's natural resources. Unfortunately, laws and institutions have often not adapted quickly enough to ensure that this development is sustainable – meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

Despite technological advances, many regions of the world suffer from serious water shortages. The world's poor are most affected by water scarcity. Today, 1.1 billion people lack access to safe drinking water, and more than twice that number lack access to adequate sanitation, mostly in Africa, Asia, Latin America and the Caribbean (WHO/UNICEF, 2004). When affordable piped water is not available, citizens use lakes, rivers or shallow wells that may be polluted or contaminated with faecal matter. Without progress, the numbers of people without access to water and sanitation will likely increase sharply with urban and rural population growth. Indeed, social scientists have introduced the term “water deprivation” – the inability reliably to obtain water of adequate quantity and quality to sustain health and livelihood – as a basic index of poverty.

I. CHALLENGES IN WATER MANAGEMENT

The challenge facing governments is not only to provide clean water and sanitation but also to oversee how that water is provided. Water supplies must be safe, sufficient for people's needs, regular (number of hours per day), convenient and affordable. Much progress has been achieved. Global figures suggest that more than five billion people are routinely provided with clean water, and three billion have access to sanitation (WHO/UNICEF, 2004). In the last 20 years alone, more than 2.4 billion people have gained access to water supply and more than 600 million have gained access to sanitation (WHO/UNICEF, 2004).

The Millennium Development Goals (MDGs), agreed on in the year 2000, challenge governments to improve economic growth, health and agriculture and to alleviate poverty. Recognizing the importance of water to human well-being, the MDGs call on the international community to halve the proportion of people without access to safe drinking water and hygienic sanitation facilities by 2015. This would require that from now until 2015, an additional 100 million people per year (or 274 000 per day) be afforded access to water – a formidable challenge. For sanitation the challenge is even greater, with services to be provided for an additional 125 million people each year (or 342 000 per day). Although many governments have committed to the task, much remains to be done. This section sets out some examples of current water management challenges.

1.1. Health

The availability of clean water and sanitation is a key determinant of human health. Its absence causes or contributes to many diseases which lead to high rates of morbidity and mortality. Millions of people, particularly in developing countries, die each year from water- and sanitation-related illnesses.

The most common water-related ailment is diarrhoea. An estimated 1.6 million people die every year from diarrhoeal diseases (including cholera), and 5.4 billion cases of diarrhoea every year are attributable to poor water, sanitation and hygiene (Hutton and Haller, 2004). A range of parasitic infections caused by poor sanitation could be addressed through improvements in water management. Skin and eye infections are also common health problems related to water and sanitation. One example is

trachoma, which is spread by eye-seeking flies that breed in areas with poor environmental sanitation. Trachoma has infected 146 million people worldwide, including 6 million who have been made completely blind by the disease. It is the leading cause of preventable blindness in the world (UNDESA, 2006). Vector-borne diseases, including Japanese encephalitis, filariasis, schistosomiasis, dengue fever and malaria, also infect and kill millions every year. Malaria infects 300 million people annually, the majority in Sub-Saharan Africa (UNDESA, 2006). Malaria, filariasis and dengue fever are all spread by mosquitoes, which breed in stagnant water. Other health dangers related to water include water pollution caused by industrial contamination and agricultural practices, leading to the leaching of pesticides, fertilizers and other chemicals into water sources.

1.2. Agriculture

Despite a quadrupling of the world's population during the twentieth century, world food production at the end of the century was sufficient to meet global caloric needs (Shah and Xepapadeas, 2005). Water stored and diverted for irrigation played a particularly important role in this achievement, irrigating 40 percent of global crop production (WWAP, 2003). In the last century, intensification of irrigation created a 13-fold increase in the world's consumptive use of water and today, irrigated agriculture is the single largest user of water. Estimates vary, but the general figure quoted is that agricultural uses make up 70 percent or more of total water withdrawals.

Population and food needs will continue to increase as the world's population increases to nine billion or more by the middle of this century. The International Food Policy Research Institute and the International Water Management Institute examined the impact of the growing human population on water and food and projected an expected increase of 17 percent in water withdrawals for irrigation (Rosegrant *et al.*, 2002). Nonetheless, with appropriate technologies, significantly less water could be consumed in meeting future needs. For example, farmers currently lose half of the water they abstract due to seepage in the delivery of water to their fields. Technology and improved water use efficiency could increase the reliability of water supply to agriculture and increase water availability.

1.3. Hydropower

The energy harvested from water as it moves through the water cycle is an important component of the world's energy supply. In the last century, hydroelectric power harnessed through large dams provided almost one-fifth of the world's electric power production. In some countries, hydropower makes up over 90 percent of electric power (e.g. Brazil, Honduras, Laos, Mozambique, Norway, Tajikistan) (WWAP, 2003). However, more than two billion people still have no access to electricity, whilst electricity consumption has grown rapidly – doubling in the last 20 years. As a result, local pressures to continue developing hydropower potential remain. Although industrialized countries have seen a rapid drop in new dam construction (having reached capacity in earlier decades), in many regions much of the potential for hydropower remains unexploited.

Structural and capital-intensive engineering solutions – particularly large dams and associated irrigation and power schemes – have provided communities with massive amounts of water, food and power and have caused improvements in human development. On the other hand, dam construction has destroyed critical ecosystems, endangered certain species and displaced millions of people (WCD, 2000). In 2000, the World Commission on Dams released a report, *Dams and Development: A New Framework for Decision-Making*, which noted that over the past 50 years, dams have fragmented and transformed the world's rivers, displaced 40 to 80 million people in different parts of the world and caused significant adverse impacts on human health and the environment (WCD, 2000). The report also found that by creating standing bodies of water, hydroelectric facilities may have increased the incidence of water-related diseases such as malaria, dengue fever and schistosomiasis.

1.4. Ecosystems

Efforts to harness and develop water resources for the sake of human development have indisputably degraded the environment. Changes to the hydrograph and related physical, chemical and biological processes have substantially degraded inland water ecosystems throughout the world. The impacts of water resource development on ecosystems occur in a number of ways, but the main effects arise from the removal of water from inland water systems, which alters the distribution and availability of the remaining waters.

The amount of water withdrawn from inland water systems has increased an estimated 15 times over the past 200 years (Vörösmarty *et al.*, 2005). Changes in river flow resulting from infrastructure development and land conversions have also had ecological impacts on watersheds, water temperatures and upstream and downstream ecosystems, particularly in terms of nutrient load and sediment transport. These activities may negatively affect deltas and fish migrations, destroy or degrade fish and waterfowl habitats and harm the livelihoods and food security of local delta populations (WCD, 2000). Poorly managed watersheds can also degrade the level and value of ecosystem services such as water purification and erosion control.

Recognition of the extent and severity of the effects of water resource development on ecosystems has led to efforts to avoid, minimize and mitigate the consequences (WCD, 2000; Vörösmarty *et al.*, 2005; Aylward *et al.*, 2005). This has led to proposals to create environmental flow regimes, employing a number of engineering, economic and legal tools to restore the ecosystem function of river systems (Dyson *et al.*, 2008).

1.5. Social development

Unlike the situation in most OECD countries, in many developing countries neither water quality nor quantity can be assumed. Because water supply infrastructure is not provided in the poorest urban areas or in many rural areas, obtaining water is regarded as an individual or domestic responsibility. In contrast to the ease of turning on a faucet, lack of infrastructure means a high labour input as members of the household (generally women and girls) must collect each day's water, whether from a communal pond or well, tanker or kiosk. One billion people do not have water within a 15-minute walk of where they live (Vidal, 2003). The average daily time spent on collecting water in 1997 across East Africa was 91.7 minutes per day, triple the time spent 30 years earlier (Thompson *et al.*, 2000).

Where communal or free water sources are too far away or contaminated, poor people purchase their water from street vendors or tanker trucks. Forty percent of those surveyed in an East African study used water vendors (Thompson *et al.*, 2000). The price of water from vendors is always higher than the price from municipal supply systems – on average 12 times higher (Segerfeldt, 2005) – with the tragic irony that the poorest in society are paying the most for their water. The resulting social and economic impacts are immense. With a significant proportion of women and girls' time and

family income dedicated to procuring domestic water, opportunities for productive activities such as education or employment are reduced. It is no exaggeration to say that the introduction of piped water and improved infrastructure can transform the social and economic fabric of a community.

II. MANAGING WATER RESOURCES

In its natural state, freshwater varies considerably in terms of its availability. Water resource development efforts (construction of dams and irrigation channels, widening of river embankments to improve navigation, drainage of wetlands for flood control, etc.) have resulted in the replacement of naturally occurring and functioning systems with highly regulated and modified human-engineered systems. These “developed” systems have typically been designed solely for the satisfaction of the major human consumptive uses (irrigation, municipal and industrial use) or non-consumptive uses (hydropower and navigation). Although such large-scale projects may have improved efficiency in the collection and provision of water for a number of important human needs, they may also have caused harm to human health and the environment.

Unforeseen adverse impacts of past water development efforts and ongoing shifts in ecological, social and political forces have changed the landscape of water management in the early twenty-first century. A number of forces influence and drive change in the management of water resources (Aylward *et al.*, 2005; Finlayson and D’Cruz, 2005; Vörösmarty *et al.*, 2005). Population growth, increased urbanization, industrialization, political instability, conflict and climate all play a role in the drama of water scarcity. Responding to current and future water management challenges will require careful consideration of these different influences, in order to balance water resources development with the management of ecosystems.

Population growth is directly linked to increased water pollution, higher demand for water for domestic purposes and an escalating need for water to irrigate the crops necessary to supply greater amounts of food. Increasing wealth with its concomitant rise in the standard of living in certain regions puts pressure on water resources as wealthier populations use more water and pollute more (Aylward *et al.*, 2005; Finlayson and D’Cruz, 2005; Vörösmarty *et al.*, 2005).

Industrial development strains both the quantity and quality of existing water resources and affects water management. Low production costs in developing countries have attracted investors, although regulatory frameworks and enforcement capacity may be weak. Activities such as mining and chemical production can directly and negatively affect water resources. Industrial compounds, agricultural pesticides, fertilizers and industrial wastes have entered key water sources, polluting them and aggravating water scarcity. The poor and disadvantaged are disproportionately affected by water scarcity and water pollution, placing livelihoods, health and security at stake.

Increasing urbanization is another challenge to water management. Approximately half of the world's population now lives in urban areas, compared to around one-third in 1972. The total urban population is projected to swell by 2030 to nearly five billion people, with the greatest urban growth taking place in Asia and Africa (UNFPA, 2007). High concentrations of urban residents increase local water demand and water pollution, overload sanitation infrastructures and harm groundwater sources. On the other hand, urbanization can provide options for urban and peri-urban farmers to rely on the nutrient loads in wastewater for improved nutrition and household savings.

Over-exploitation of underground aquifers near major urban centres has resulted in sinking water tables in many cities. The remaining groundwater is often degraded from inadequate wastewater treatment, anthropogenic pollution and saltwater intrusion (in coastal areas). Poor sanitation leads to contamination of water by pesticides, nitrogen, phosphorus and raw organic matter containing undesirable residues. Sustainably managing water consumption and waste discharges in urban areas is therefore one of the major issues for the future. Clean, safe and sustainable urban water flow is necessary not only for the survival and health of city populations but also for the smooth functioning of industry, hospitals and municipal infrastructure.

Global climate change poses additional challenges for successfully managing water resources. Climate change may increase the frequency of extreme weather events such as floods, fires, drought, cyclones and hurricanes (hydro-meteorological events). Extreme weather events may increase the prevalence of outbreaks of infectious disease; lead to loss of land (as a result of rising sea levels); damage fish stocks and agricultural outputs; threaten water supplies; damage infrastructure and communications; interrupt

economic activities; and magnify social problems such as poverty and overcrowding. The annual impact of climate change is projected to be more than US\$ 300 billion (Munich Re Group, 2000).

As the climate changes, current patterns of water scarcity, drought and floods will shift and have consequent effects on river flows and groundwater recharge. Natural ecosystems may suffer potentially irreversible effects. Climate change may also degrade water quality through increasing pollutant loads as river systems suffer from low flows and water stress. Water planners and managers will have to accommodate the resulting changed availability of water resources for ecological and human needs.

Efforts to address population growth, urbanization, industrial development and climate change are beyond the scope of this book, as they are not within the purview or control of the water resources community. However, the impacts of these forces on water resources must be brought to the attention of policy-makers working toward sustainable water resources management.

“Water resources management” can be defined as all efforts related to the use of water to meet human and ecosystem needs. Water resources management is not the same as water resources development. Development can include the construction of dams for water storage, channels for irrigation and river embankments for navigation; the draining of wetlands for flood control; and the establishment of inter-basin connections and associated water transfers. Water resources management, by contrast, is both a scientific and a political undertaking, occurring within the context of national laws and regulations, international treaties and biological and ecological technologies. Water resources management activities range from planning water resources development to monitoring and evaluating water contamination.

Lack of access to water, sanitation, power and adequate nutrition, as well as the degradation of ecosystem function and biodiversity, suggest an emerging crisis in the water resource field (Rijsberman and Scott, 2005). However, a central factor of the “water crisis” is lack of proper resource management. At its core, improper water management is often a failure of governance – a failure at the level of policy, legislation, regulation and the application of economic incentives. More specifically, it is a failure to create adequate institutional arrangements (rules, regulations, norms and incentives) for governing freshwater ecosystems, water and water-related services.

A variety of interventions and tools can positively address water resource management problems. Regulatory interventions directly influence decisions on water governance and management. For example, rules can regulate how water is abstracted from rivers, assess fines for discharge of pollutants and control how new dams are constructed. Rules may mandate that when a wetland is converted, another wetland be protected or restored as mitigation. Scientific understanding of the water cycle must be linked to the legal and regulatory tools necessary to provide incentives to individuals and groups to manage water sustainably.

Proper water governance will be critical to meeting human and ecosystem needs and avoiding water-related crises. The world's freshwater must be shared sustainably among individuals, economic sectors and sovereign nations, whilst respecting the environment. Minimizing threats whilst striking a balance between equity and efficiency in the allocation and use of water is the goal of water resources management and regulation.

III. THE ROLE OF LAW IN WATER MANAGEMENT

Well-designed water legislation creates an enabling environment for effective water resources management. Good legal frameworks may enhance peaceful cooperation and resource-sharing, allowing governments to implement and enforce policies to ensure sustainable and equitable allocation of water.

3.1. National water legislation

Although the role of law in society varies from country to country, the central importance of water law is widely recognized. Through water legislation, governments seek to ensure that water resources are readily available to meet the needs of each sector of society. Yet many nations' legal provisions on water are scattered throughout laws related to different uses, such as irrigation, industry, municipalities or hydropower. For example, legal provisions concerning water supply, quantity and quality may be located in separate pieces of legislation addressing energy, the environment and public health. The policies and objectives of these sectoral laws may be redundant, inconsistent or even contradictory, placing various stakeholders at odds and making effective management difficult. The net result may be gaps, inefficiencies, an overlap of powers or a fragmentation of water management efforts, leading to inefficient and unsustainable water use. Instead of this patchwork approach, many countries are rigorously reviewing the national

legal frameworks that govern their water sectors and making appropriate changes to achieve more effective water management.

Comprehensive water legislation will be effective if it reflects the political and cultural structure of a nation and integrates all water-related concerns. Each country has unique politics, traditions, international obligations, institutions, resources and history, all of which affect the development and implementation of water legislation. Any new water law should account for these factors to ensure that it is closely tailored to national circumstances and local capacities. Moreover, modern water legislation must consider domestic water uses and management against the backdrop of international and regional agreements. The ultimate goal is an integrated national legal framework that respects international commitments, incorporates all aspects of water use and rights and takes into account human health and sustainable development.

National water legislation has traditionally focused on administration and enforcement efforts, for example by establishing rules and procedures for water use and imposing penalties for breaches and violations. More recently, governments have also adopted economic instruments – such as effluent taxes, abstraction charges, tradeable abstraction and pollution permits and subsidies – to influence individual and corporate behaviour in order to achieve policy objectives. These economic tools complement classic regulatory instruments such as maximum pollution-load limits or permits for water abstractions and wastewater discharges.

A wide range of stakeholders must be consulted throughout the process of drafting and adopting water law. Governments should consult professionals in the fields of law, health and environmental protection; scientists; NGOs; local government administrators who will face the practical challenges of implementation; and citizens representing a variety of water uses. Elites, donors, “experts” and other groups must not overpower or ignore the inputs and voices of the water users themselves, who may be poor, unable to speak the official language of the state or otherwise disenfranchised. As noted earlier, it is often the poor whose access to water is most at risk.

True consultation requires a commitment to listen to and understand the needs, objectives, insights and capacities of the intended users and others potentially affected by the law, and to find ways to accommodate the multiple interests at stake. By helping create a broad-based consensus in

favour of the law, participation improves compliance and fosters a wide sense of “ownership”. Laws that reflect stakeholders’ perceptions and views may stimulate organized support and active pressure for the laws’ enforcement, as opposed to indifference or even passive resistance. At the very least, public participation publicizes the legislation to society at large.

3.2. International developments

The need for regional and global water management grows stronger each year. Some transboundary water conflicts are longstanding, whilst new and increasingly volatile water-related conflicts can be expected to arise as water scarcity increases. International water resources – whether lakes, rivers or groundwater – face increasing pressure from abstractions and pollution. Because of the expansive geographic network of water flow and currents, even when national water policies appear to be addressing purely local problems, the ramifications may be regional or worldwide. Nations will have to work in concert to find lasting solutions.

National water legislation is frequently inspired and guided by agreements signed at international or regional level. Some treaties or conventions cover many countries and watercourses, whilst others cover a particular transboundary river, lake, basin or aquifer. Nations’ new or revised legislation should be informed by those agreements to which they are signatories. To best address emerging international water concerns, governments should establish joint water management plans, surveillance and early warning systems and contingency plans with neighbouring countries, and should exchange information and knowledge.

IV. BOOK OVERVIEW

The ten chapters of this book are designed to bridge the gap between the practice and science of water resources management on the one hand, and the law of water resources management on the other. The chapters describe the legal and regulatory frameworks for water management in a manner comprehensible to scientists and health professionals, whilst discussing the science of water management in a manner comprehensible to policy- and law-makers. The book identifies how law and science may be applied to water-related challenges, amongst them pollution, water scarcity, use of wastewater and access to drinking water.

An increasing number of countries are reviewing their water policies, water management strategies and legislative frameworks. This book can serve as a resource not only for water management professionals and water lawyers, but also for policy-makers interested in learning about water law, water resources management and emerging water-related issues.

The book contains the following chapters:

Chapter 1: Introduction

This introductory chapter explains how water and water management affect health, social and economic development and environmental sustainability. It describes current trends in water resource management, focusing particularly on the challenge of meeting the competing water needs in society. It then turns to the role of law in water management, demonstrating how good legal and regulatory frameworks underpin sustainable, effective and integrated water management, and arguing that water law and policy should reflect users' real needs and priorities and be tailored for each specific national context. It concludes with an overview of the remaining chapters.

Chapter 2: Water Resources and Their Management

Chapter 2 provides an introduction to basic water management concepts and terminology. The chapter describes the classifications of fresh water bodies (surface water, groundwater, reservoirs and others), presents the types and sources of water resources and outlines the water cycle. It discusses the relationship between human and ecosystem demands and explores the principal water uses, including domestic water supply, agriculture, industry, transportation, energy production, recreation. The chapter also explores the concepts of blue and green water, which are increasingly used to understand water scarcity and to determine how best to fulfil human and ecosystem water needs. It concludes by introducing the main objectives and concepts of water management and the currently available tools and technologies.

Chapter 3: Water Governance: Policy and Legal Frameworks

Effective water legislation must be grounded in sound policy. Countries may need to revise existing policies or create new ones to reflect the changing conditions of national water resources. Chapter 3 introduces water policy and explains its role in the governance of water. The chapter then examines

the laws, regulations and standards through which national water policy may be implemented. It describes best practices and desirable features of modern water laws, provides examples of water legislation from around the world and suggests ways of addressing the challenges of water resources management and water services provision.

Chapter 4: International Water Law

Just as water should not be managed and legislated by disparate sectors within a particular country, individual countries should not manage water in isolation. Coordinated, multinational responses to water scarcity and water problems are critical to achieving effective management of shared water resources. Chapter 4 provides a brief overview of international law and then describes international water law in detail. It introduces binding and non-binding sources of international water law, including water-related treaties, conventions and agreements, basic principles of international customary law and guidelines for water management and water services formulated by international organizations. The chapter concludes with a discussion of emerging principles in international water law.

Chapter 5: Water Resource Quantity: Allocation and Management

Chapter 5 explores the challenges of water allocation and management. The timing and location of water availability affect water quantity: water is often unavailable in the right quantity at the right time and place and is therefore considered “scarce” relative to the demands placed on it for human use and consumption. Moreover, human alteration of the landscape and natural water flows has routed water away from ecosystems upon which many species of animals and plants depend, endangering their survival.

This chapter describes management of three essential water resources: watersheds, groundwater and surface water. It outlines the complex challenges – technical, economic, institutional and regulatory – that must be addressed in order to allocate and manage water sustainably. In particular, there is a tension between the desire to manage water as a private good and the growing recognition that leaving the allocation and management of water to the market can have adverse effects on the social and environmental values of water. The chapter concludes by reviewing examples of national regulatory approaches to managing water quantity addressing real and potential conflicts.

Chapter 6: Water Resource Quality

Water pollution reduces the quality of water, making it unsuitable for many uses, most notably drinking water and ecosystem health. Chapter 6 addresses water quality problems. It reviews the hydrology of freshwater systems and the nature and sources of water pollution. It then looks more closely at two principal categories of water pollution: point source pollution (pollution of water systems by discrete and identifiable facilities and outfalls) and non-point source pollution (pollution delivered to water systems through surface water runoff, infiltration and other unchanneled means). The chapter also considers the social, economic and health effects of water pollution, the principles that inform government responses to pollution and the legislative and regulatory tools and strategies typically deployed in water pollution control.

Chapter 7: Drinking Water

Ensuring access to clean, healthy drinking water is one of the principal challenges of water management. Lack of access to clean drinking water results in the deaths of millions of people every year and harms the health of many millions more. Chapter 7 discusses the effects of lack of access to safe drinking water, both in social and economic terms. It describes policy and regulatory efforts to increase access to water and to improve its safety and quality. The chapter concludes with a detailed discussion of legislative and regulatory options for drinking water quality standards and laws, drawing on the World Health Organization's *Guidelines for Drinking-Water Quality*.

Chapter 8: Water and Agriculture

Chapter 8 explores the relationship between water and agriculture. Globally, more than two-thirds of all freshwater goes towards food production. The world's expanding population will require even more water to produce food, yet there are limited freshwater supplies. On the other hand, increasing urbanization can be expected to produce greater quantities of wastewater, which represents an opportunity since the nutrients in wastewater can increase food production whilst enabling farmers to spend less on fertilizers. The chapter presents the legislative and regulatory frameworks that govern irrigation practices and explores policy options and good practices for making irrigation more efficient whilst protecting public health and the environment.

Chapter 9: Integrated Management of Water for Human and Ecosystem Needs

The failure to effectively manage water resources has caused problems related to both water quantity and quality. Addressing the need to balance water use for human development and ecosystem protection, Chapter 9 outlines the significant benefits of improved watershed and groundwater management, introducing the concepts of environmental flows, watershed services and conjunctive management of surface waters and groundwater. It then considers how regulatory and market-based tools can meet future water resource management challenges. These tools include limits on water use and pollution, land use zoning, cap and trade systems, water taxes and subsidies, irrigation water pricing and demand management, incentives for agricultural water conservation and water quality trading.

Chapter 10: Conceptions of Water

The concluding chapter outlines three conceptions of water that can be expected to remain on the international stage in the coming years. These are water as a commodity, water as a service and water as a human right. International debate will continue on whether and how water should be covered under international trade rules, and international and national efforts will continue to recognize and define the human right to water. These conceptions of water should be weighed and considered by those who manage water quantity and quality, elaborate water policy and craft legislative solutions to global and local water problems.

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WATER RESOURCES AND THEIR MANAGEMENT*

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This chapter provides a foundation for understanding the biophysical aspects of water management. It introduces the concepts, objectives and tools used in water management and provides the relevant terminology. It begins by describing the characteristics of the water cycle. It then sets out the types and sources of water resources. The chapter classifies the principal types of water uses, estimates their demand and discusses the relationship and potential conflicts between human and ecosystem needs. The chapter concludes by outlining the need to adopt integrated water resource management strategies.

I. THE WATER CYCLE

Water is a renewable but finite resource. It is neither created nor destroyed; it only moves from place to place and changes in quality. Under current estimates, the earth has about 1 386 million km³ (cubic kilometres) of water. However, the vast majority of this is of little direct use to us. Over 97 percent of available water is saline and only 2.5 percent is freshwater. Moreover, much of this freshwater is locked in the polar icecaps and glaciers.

Freshwater can be defined as water having a low concentration of salts, or water that is generally accepted as suitable for abstraction and treatment to produce potable water. Salt water is generally defined as water containing more than 1 000 parts per million of dissolved salts of any type. This book focuses on freshwater and its uses.

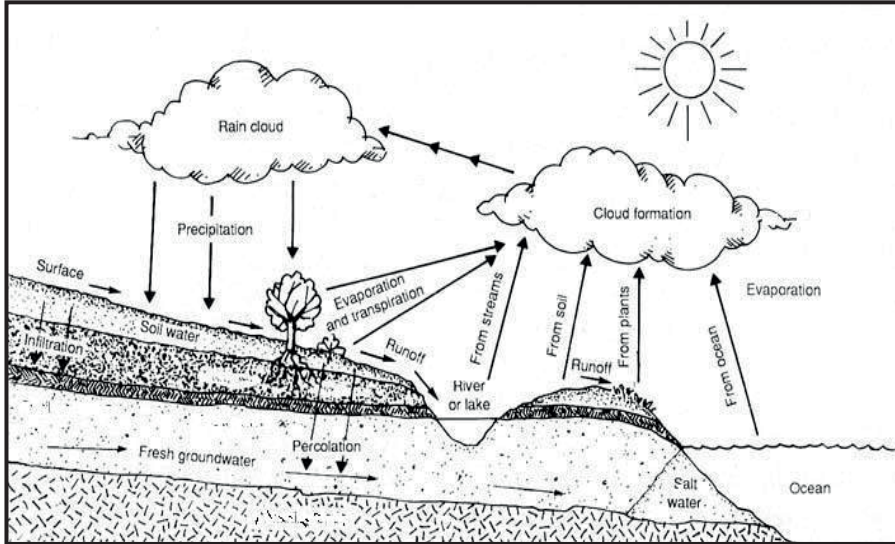
The movement of water on the earth's surface and through the atmosphere is known as the hydrologic cycle or water cycle. As illustrated in Figure 2.1, the atmosphere takes up water as vapour from the earth's surface through evaporation from the soil and from water bodies, and through transpiration from plants. Evapotranspiration is the term used to describe the return of water from the surface to the atmosphere.

Wind moves water vapour from place to place until it condenses to form rain clouds. Water returns to the surface of the earth as either liquid or solid precipitation. Liquid precipitation includes rain, dew, drizzle and fog-drip. Solid precipitation comprises snow, sleet, hail and hoarfrost (the solid equivalent of dew).

Most precipitation is either intercepted by vegetation or infiltrates the soil. The precipitation that is not absorbed by plants or soil is called runoff, and it

flows downhill over the ground surface until it reaches a river or other surface water body.

Figure 2.1 - The Water Cycle



Source: FAO, 1993.

The precipitation that does enter the ground, adding to the underground water table, is called infiltration. Infiltration may first replenish soil water, serving as a source of water for plant transpiration. Infiltration percolating further downwards (by means of gravitational or capillary forces) enters underground geological water systems called aquifers, which hold groundwater. This process is known as aquifer recharge or groundwater recharge. Aquifers usually have an outlet to surface waters (rivers and lakes) or the sea. The outward flow of water from groundwater into surface waters is called groundwater discharge or return flow. These terms are defined in greater detail in Box 2.1.

If groundwater levels fall, so, too, will most surface waters. Water in rivers and lakes then flows to the oceans from which water evaporates in an ever-repeating cycle. Indeed, our world's water systems are best understood not as a series of discrete and separable water bodies, but rather as a complex and inter-related network within which many natural cycles and processes are constantly in motion. For example, through the cycle of evaporation and

precipitation, water molecules from surface moisture become airborne and then return to the earth as rain and snow, feeding the streams, tributaries, rivers, lakes and oceans that provided the bulk of the evaporate in the first instance. Groundwater and surface water are also inter-connected. Groundwater bodies generally both discharge to and are recharged by surface waters. In times of drought, pumping groundwater contributes to depletion of the remaining surface waters as well.

Box 2.1 - Subterranean Definitions

Soil water rests in the spaces between particles of soil and is immediately available to plants. The amount of water in the soil depends on the soil texture. Soil water occupies the shallow layer of earth, called the *unsaturated zone*, which is located directly above the water table.

The *water table* is located at the top of the groundwater and indicates the depth from which water can be extracted. When the water table falls, wells run dry and extracting water becomes more difficult. The water table rises after groundwater recharge, and declines with seasonally dry weather, drought, reduced infiltration caused by compaction and other factors.

Aquifers are rock formations, usually composed of sandstone, chalk and limestone, that are sufficiently porous to contain water and through which water may percolate. Aquifers may be *confined* or *unconfined*. Aquifers are unconfined when the rock formation that contains the aquifer is at the surface or is overlaid by permeable soils. Water may enter the aquifer directly from the surface or after passage through the soil, and the water levels are subject to seasonal fluctuations. Clays and other types of impermeable rocks or soil overlie confined aquifers.

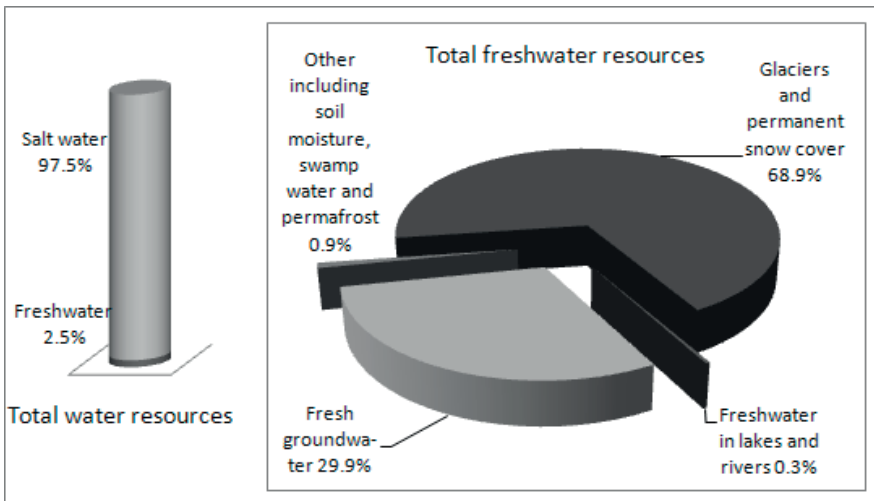
Water does not enter confined aquifers directly from the surface but through unconfined aquifer outcrops. Water levels in confined aquifers are not subject to seasonal fluctuations and may be almost completely depleted by excessive pumping. In a *perched aquifer* the water is stored above an impermeable layer and has no outlet; once full it spills water to the aquifer below.

Fossil groundwater is held in aquifers located at great depth that have little if any connection to groundwater recharge. Once extracted (or “mined”), these groundwater reserves are difficult to replenish.

The water cycle takes place within the earth’s ecosystem. Without water, plants wilt, shrivel and die. Even viruses, which may not even be alive, go dormant and “turn off” without water. Because of the inter-relatedness of natural resources and systems, it is difficult to effectively manage the use of one natural resource without damaging the planet’s subtle and fragile equilibrium. Human interventions can cause a series of reactions in the environment; for example, changes in vegetation and land use affect the quality and the availability of water resources. This is true with respect to surface water, groundwater and precipitation.

The ways in which environmental changes affect water resources may be loosely classified according to whether they are primarily related to water quality or water quantity. Soil erosion, sedimentation and nutrient outflow affect water quality in downstream runoff or surface water. Changes in annual water yield, seasonal flow, stormflow response and groundwater recharge affect the quantity of water received downstream (the stream hydrograph). Changes in local or regional vegetation may lead to localized or basin-wide shifts in rainfall and precipitation. For example, elimination of certain forest areas may reduce precipitation previously captured from fog in upland cloud forests. Regional climate also has an important influence on the hydrologic system and is affected by a wide range of human activities.

Figure 2.2 - Global Water Resources



Source: Shiklomanov, 1998.

II. SUPPLY OF WATER RESOURCES

2.1. Freshwater resources

Roughly 2.5 percent of the earth's water resources are freshwater. The total stock of freshwater is equivalent to a volume of water over 70 metres high spread across the land surface area of the earth. Much of this water, however, is locked up in long-term storage, leaving very little available to humans and the environment. In fact, more than 68 percent of this freshwater is in the form of ice and permanent snow cover in the Antarctic, the Arctic and mountainous regions. A further 30 percent of freshwater is stored underground as groundwater, although estimates of the amount of water in aquifers vary. Ice in the permafrost zone makes up the next largest amount, at just less than 0.75 percent of the world's freshwater. Finally, approximately 0.3 percent of freshwater is concentrated in lakes, reservoirs, wetlands and river systems, and an even lower percentage (0.1 percent) of water is retained at any given time as soil moisture.

There are two types of freshwater resources: freshwater in static storage and freshwater in transit. Freshwater resources in static storage include freshwater in the form of glaciers, permafrost and ice, whose complete renewal takes place over many years or decades. Freshwater resources in transit are those water molecules moving actively through the water cycle. Freshwater resources are both renewable and exhaustible. Both types of freshwater are fully replenished during the hydrologic cycle, but at very different rates. The complete recharge of permafrost and ice takes roughly 10 000 years, and the complete recharge of deep groundwater and mountainous glaciers about 1 500 years. Intensive use depletes stored waters and disturbs the natural systems that depend on these freshwater sources. In some circumstances, these ecosystems cannot be restored once disrupted.

The hydraulic connection between groundwater and surface water (rivers and lakes) must also be recognized. The influence of groundwater recharge or groundwater discharge is felt both in terms of volume changes (for example in static storage) and in terms of pressure within the hydraulic system. Just as additions (or not) to one end of a garden hose will affect the water emerging from the other end, groundwater recharge and withdrawal affect the rate and volume at which groundwater rejoins surface waters.

Table 2.1 - Stocks and Flows in the Hydrosphere

Type of Water	Stock of Water			Flows
	Volume (¹ 000 km ³)	Fraction of Hydrosphere (%)	Fraction of Freshwater (%)	Annual Volume (¹ 000 km ³ /yr)
<i>1. Saline Waters</i>				
Seawater (oceans)	1 338 000.0	96.5	-	452
Groundwater – saline	12 870.0	1.7	-	
<i>2. Freshwater</i>				
Glaciers/perma- nent ice	24 100.0	1.74	68.7	
Groundwater – freshwater	10 530.0	0.76	30.1	
Ice in permafrost	300.0	0.022	0.86	
Lakes (fresh)	91.0	0.007	0.26	
Soil moisture	16.5	0.001	0.05	80
Wetlands	11.5	0.0008	0.03	
Rivers	2.1	0.0002	0.006	39
Biological water	1.1	0.0001	0.003	
Atmosphere	12.9	0.001	0.04	525
<i>3. Totals</i>				
Hydrosphere (all water)	1 385 935.1	100	-	
Freshwater	35 065.1	2.53		525
Blue water	105.7	0.008	0.0030	39
Green water	16.5			80

Sources: Shiklomanov and Rodda, 2003; Shiklomanov, 2000; and L'vovich, 1979.

The quantity of freshwater moving through the earth's surface is regenerated by precipitation. Estimates of total global annual precipitation vary between 525 000 and 577 000 cubic kilometres (km³) (Shiklomanov, 2000; UNESCO, 2000). Of this, around 119 000 km³ falls on land and the rest falls into the oceans

(Shiklomanov, 2000; UNESCO, 2000). This is the annual flow-through volume of freshwater potentially available for human and ecosystem needs.

The difference between rainfall and total runoff from rivers (including groundwater discharge) represents total terrestrial evapotranspiration (the evaporation of water from the earth's surface and from the transpiration from plants). The volume of terrestrial evapotranspiration is estimated at roughly 73 000 km³/yr (Falkenmark and Rockström, 2004). Water that moves through evapotranspiration is often referred to as green water (in that it cycles largely through plants). This water is different from blue water, which includes all freshwater discharged from river basins (Falkenmark and Rockström, 2004).

The amount of water that percolates through to aquifers is estimated at 7 500 km³/yr – the difference between evapotranspiration (72 500 km³/yr) and the annual soil moisture turnover (80 000 km³/yr) (see Table 2.1). In equilibrium, groundwater recharge naturally discharges to surface waters, as described above.

Many efforts have been made to calculate annual flows of freshwater. Vörösmarty *et al.* found that the different estimates range from 33 500 km³ to 47 000 km³ for long-term renewable runoff from land surfaces. These are large numbers and one might conclude that such a large amount of freshwater should more than satisfy human demands. The problem, however, is that insufficient freshwater is available to humans *in the amounts and at the time and location needed*. Thus the global supply of freshwater can prove a misleading statistic. What matters is not the total amount of freshwater on earth but, rather, whether a community has access to enough freshwater when it needs it.

2.2. Sources of freshwater

Precipitation, surface waters and groundwater are the main types of water sources from which freshwater is available for human or ecosystem use.

2.2.1. Precipitation

Precipitation is largely composed of rain and snow. It (along with the resulting soil moisture) feeds plants and animals and makes human life possible. It is estimated that 60 to 70 percent of global food production

comes from rain-fed agriculture, and that 90 percent of evapotranspiration (or green water vapour) is related to plant production in terrestrial ecosystems (Falkenmark and Rockström, 2004). When rainfall exceeds the soil's capacity to absorb, excess water (runoff) flows downhill over the ground surface until it reaches a river or other surface water body. Of total stream runoff available each year, 30 percent is available on a generally constant basis, whilst 70 percent occurs through flood flows (Falkenmark and Rockström, 2004).

Humans have long harvested rainwater to meet personal, household, agricultural and livelihood needs. Today, new technologies are being devised whilst old and indigenous techniques are being explored and renewed to reduce human dependence on surface waters and groundwater extraction. In remote and rural areas, investments in rainwater collection from rooftops and in small tanks or ponds are increasingly part of small-scale development strategies. In areas where fog or low clouds are prevalent (such as coastal Angola, Central America or Chile), water may be harvested from water vapour through vegetation (forests) or human-erected structures. Scientific advances have led to new technologies to alter precipitation patterns. For example, cloud seeding can induce solid or liquid precipitation over target lands.

2.2.2. Surface water

Surface water resources include rivers, streams, lakes, channels and ponds. Although the freshwater in rivers and lakes accounts for only 0.3 percent of freshwater on earth, it is the most accessible to humans and vital for freshwater ecosystems. Rivers can be classified according to their catchment size, flow volume or other criteria. Perennial rivers carry water year-round, whereas intermittent streams flow irregularly throughout the year and ephemeral streams exist only in periods of heavy rainfall. The duration and rates of precipitation, infiltration and evapotranspiration in river drainage basins and the extent and rate of groundwater discharge affect a river's volume.

Lakes are inland bodies of water occupying a hollow in the earth's surface, where water is relatively stationary and is stored for a prolonged period. Lakes, like rivers, are usually freshwater bodies. Lakes are supplied with water through precipitation that falls directly on the lake surface, through the flow of streams and rivers into the lake, through runoff from adjacent lands

or through groundwater discharge. However, many lakes, especially in arid regions, become saline because the high rate of evaporation concentrates salts.

Lakes are transient features on the earth's surface: they can appear and disappear in a relatively short period of geologic time. The rate at which a lake ages depends on several factors, including erosion and climatic changes. Moreover, a lake may gradually fill with organic and inorganic sediment, becoming first a swamp or bog and then a meadow.

The area drained by a stream, river or lake is called a watershed, catchment or basin, depending on the size of the area and local parlance. Every stream, tributary or river has an associated watershed, and small watersheds are often part of larger ones.

2.2.3. Groundwater

Groundwater consists of all waters found beneath the surface of the earth. It flows naturally to the earth's surface via springs, or can be collected and brought to the surface in wells or tunnels. Groundwater is an important source of drinking water: anywhere from one-quarter to one-half of the world's population depends on groundwater for drinking (WWAP, 2003). As noted above, groundwater constitutes roughly 30 percent of total freshwater, but makes up nearly all of the freshwater stored in the earth in liquid form. The true extent of groundwater resources is uncertain: estimates vary from 7 to 23 million km³, with 10 million km³ generally accepted as an intermediate amount (Vörösmarty *et al.*, 2005; Falkenmark and Rockström, 2004).

Only a fraction of groundwater is renewable on an annual basis. As described above, the potential annual groundwater recharge (percolating down through the earth from precipitation) is just 7 500 km³/yr. The replacement rate for the global stock of groundwater would therefore be once every 1 400 years (Falkenmark and Rockström, 2004). However, transit times for groundwater vary tremendously. Fossil groundwater is the result of water storage over geologic time and is therefore an exhaustible resource, whereas the flow of groundwater into headwater areas may have a transit time measured in days or months.

In addition to the water that naturally percolates through the ground, groundwater may be artificially recharged by a range of human actions

including injection of water deep into the ground through wells; infiltration into the ground by directing water into recharge pits; and infiltration through spreading water on fields. Intentional aquifer recharge serves two purposes: storing excess water for later use and improving water quality by using the soil's filtration capacity.

Although the soil's ecosystem service of water purification often filters groundwater so that it is safe to drink, the slow movement of groundwater also means that once groundwater becomes polluted it may remain polluted for decades. Groundwater clean-up is complex and expensive. As a result, source protection – prevention of groundwater pollution – is a central focus of water resources management.

2.2.4. Wetlands

Wetlands play a fundamental role in preserving the environmental balance of the earth and provide habitats for myriad species of flora and fauna. Wetlands are “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters” (1971 Ramsar Convention, art. 1). Scientists recognize five major wetland systems: marine (coastal wetlands, including coastal lagoons, rocky shores and coral reefs); estuarine (including deltas, tidal marshes and mangrove swamps); lacustrine (wetlands associated with lakes); riverine (wetlands along rivers and streams); and palustrine (marshes, swamps and bogs).

Wetlands are among the world's most productive environments, serving as cradles of biological diversity, storehouses of genetic material and producers of food and resources necessary for human survival. For example, rice – a common wetland plant – feeds half of the world's population (Ramsar Convention Bureau, 1997). Wetland ecosystems provide several crucial ecosystem services. They serve as natural filters for many pollutants, which are absorbed by wetland plant species and soil. Flood plain wetlands soak up and store water when rivers flood their banks, thus reducing downstream damage. And wetlands provide critical habitat for the young of many aquatic species. The importance of wetlands to the environmental health of the earth is widely recognized, and therefore the management of wetlands aims to protect and conserve these precious ecosystems.

2.2.5. Seas and oceans

Seas and oceans play an important role in the freshwater cycle, through evaporation. Unless it is desalinated, salt water cannot be used by humans. Although desalination processes are generally expensive and energy-intensive, technological advances have lowered costs. In some regions with limited water supply, desalination costs are now increasingly competitive with the costs of water conservation or water transfers. At the same time, desalination raises concerns both about the energy required to operate desalination plants and the difficulty of disposing of the heavily saline brine water discharged.

2.2.6. Artificial water sources

Reservoirs are artificially created by the construction of dams or impoundment barriers on rivers. These artificial water bodies allow for hydropower generation and facilitate seasonal water distribution for agriculture, industry and other uses. The total water stored in reservoirs behind dams is estimated to be between 6 000 and 7 000 km³, and the total reservoir surface area has reached 500 000 km² (Shiklomanov, 2000; Vörösmarty *et al.*, 2005).

Box 2.2 - The Great Man-Made River

In 1984, Libya began to move water from fossil aquifers in the desert to the densely populated coastal areas, so as to ensure a sufficient supply of water for the nation's industrial, domestic, municipal and agricultural needs. The Great Man-Made River Authority was established in 1983 to direct and implement this massive civil construction work. The project, whose final cost will be close to US\$ 30 billion, has entailed drilling more than 1 000 wells varying in depth from 450 to 650 metres. The conduit, which is four metres in diameter, is about 1 600 km long. This huge pipeline supplies water to the cities of Tripoli, Benghazi, Sirte and other settlements, and the amount of water transferred daily is over 6.5 million m³. The project's scope and scale have led some commentators to call the resulting river "the eighth wonder of the world" (UNESCO, 2001).

Dams and related water impoundments and reservoirs significantly alter hydrology and often negatively affect the environment. Dams have destroyed aquatic habitats and fisheries, caused the loss of downstream flood plains, riparian zones and adjacent wetlands and degraded river deltas. Moreover, the diminution of downstream river flows impairs water quality (because pollution is less diluted) (Rosenberg, 2000) and deprives downstream communities, regions or nations of water that may previously have been a critical component of their water resource supply.

Human control of water flow is not limited to dams: artificial watercourses may be built for uses such as water management, irrigation and transportation. For example, in Libya the so-called “great man-made river” project is bringing drinkable water to the coast (see Box 2.2).

III. DEMAND FOR WATER RESOURCES

The preceding section introduced the types of water sources that provide freshwater for human and ecosystem needs. This section introduces the types of water uses, and estimates current and future demands of humans and ecosystems for water resources.

3.1. Classification of water uses

As freshwater cascades through the water cycle, pulled by gravity towards the sea, it is used and reused in various ways. The term “consumptive use” denotes a use that partially or totally “uses up” water. After upstream consumption, there is less water remaining for downstream users. Alternatively, consumptive uses may change the characteristics or lower the quality of water, making it unfit for other uses. Examples of partially or totally consumptive uses include water for domestic and municipal needs, irrigation and industry. In a sense, this categorization is imperfect because water never disappears from the water cycle; the amount of water on the planet cannot be increased or decreased (Falkenmark and Lindh, 1976). In reality, consumptive uses either return water to vapour or otherwise remove it from the terrestrial part of the water cycle.

Non-consumptive uses do not reduce the volume of water available in a given source, which means that this volume is still available for downstream uses. Non-consumptive uses include inland navigation, recreation and water sports, fisheries, hydropower production and ecosystem maintenance.

To illustrate the difference between consumptive and non-consumptive uses, consider water storage. Water can be stored for future use through mechanisms that are either consumptive or non-consumptive. Water storage in reservoirs for future diversion is a consumptive use, since a percentage of stored water is typically lost through evaporation. The shallower the reservoir, the more consumptive the water storage. Water injected into groundwater, however, is generally non-consumptive.

Water usage can also be classified by where the water is used. Water is used *in situ* (on the land where it falls as precipitation) or instream (where it falls, collects or flows). Alternatively, water may be abstracted, diverted or withdrawn and moved to where it is needed (“abstractive” water use). For example, flood plain agriculture is an instream water use because it provides water to crops using natural flood cycles; no water is diverted or withdrawn from natural water flows. In contrast, agricultural irrigation is an abstractive use, as it requires diverting water from its natural course in rivers or underground to bring it to the fields where the crops are growing. The different classifications of water use for human and ecosystem purposes are set out below in Table 2.2.

Table 2.2 - Classification of Human and Ecosystem Uses of Water

Nature of Use	Location of Use			
	Terrestrial uses	Instream uses	Abstractive uses	Storage
Consumptive: quantity and quality	Ecosystem Primary production Agriculture Domestic		Domestic Industrial Irrigation Aquaculture	Domestic Industrial Irrigation Storage Hydropower Flood control
Consumptive: quality only	Waste discharge	Aquaculture Waste discharge		Aquaculture
Non-consumptive		Capture fisheries Recreation Ecosystems Barrage run-of-river hydro-power	Diversion run-of-river hydropower	Aquifer recharge Recreation Capture fisheries

3.2. Human consumptive uses

A review of the different human consumptive uses of freshwater begins with the three major consumptive uses: domestic, industrial and agricultural.

3.2.1. Domestic use

Domestic water uses are essential for survival and for hygiene. Domestic water use includes drinking, washing, sanitation, cooking and other activities, including the watering of gardens or domestic animals. Generally, these are abstractive uses (i.e. withdrawal of water from a source for use). Domestic uses may be urban or rural.

The World Health Organization (WHO) has not issued guidelines on the amount of domestic water necessary to promote or preserve good health. However, it is estimated that the minimum amount of water for domestic use per person must be 20 litres per person per day to fulfil basic needs, whilst optimal access requires 100–200 litres per person per day to meet consumption and hygiene needs (Howard and Bartram, 2003).

Although people everywhere need and use water for domestic purposes, the confluence of population growth and increased urban migration has made cities the largest users of domestic water. Water is delivered to houses, apartment buildings, public buildings (such as offices, hospitals and schools) and also to businesses and small industries located in urban areas. Water is also used by cities to wash streets and to maintain public gardens and parks. The amount of water withdrawn for municipal uses depends on the size of the population served and the services and utilities provided. Urban water use may also hinge on the regional climate and the efficiency of the public water supply system, in particular how much water is lost to leakage as a result of cracked pipes and aging infrastructure.

Most of the water withdrawn by urban water supply systems is returned as wastewater to the hydrologic system. Sewerage systems collect wastewater from private and public buildings and may treat and process the sewage before it is discharged into receiving water bodies. Treated sewage water may be released either directly to surface waters or to groundwater through recharge systems. In some cities, treated sewage water (so-called “grey water”) may be used to water plants in urban parks and gardens or to irrigate agricultural land. In some countries, cities and regions, however, wastewater

is not treated before being discharged back into the hydrologic system, creating public health risks.

Domestic water use in rural areas is generally lower than in municipal areas for a variety of reasons, including lower population density, fewer public water services provided and lower per capita water use by the poor, amongst other factors.

Table 2.3 - Per Capita Requirements for Water Service Level to Promote Health

Service Level	Access Measure	Needs Met	Level of Health Concern
No access (quantity collected often below 5 litre/capita/day [l/c/d])	More than 1000 m or 30 mins. total collection time	Consumption: cannot be assured Hygiene: not possible (unless practised at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000 m or 5 to 30 mins. total collection time	Consumption: should be assured Hygiene: hand washing and basic food hygiene possible; laundry/bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered thru one tap on plot (or within 100 m or 5 mins. total collection time)	Consumption: assured Hygiene: all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption: all needs met Hygiene: all needs should be met	Very low

Source: Howard and Bartram, 2003.

WHO reports that of the global total of 1.07 billion people without access to improved drinking water, 84 percent live in rural areas (WHO/UNICEF, 2006). Access is defined as being able to collect at least 20 litres per day of safe drinking water from a source located no more than one kilometre from the home. Improved drinking water is defined as access through household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collection. There is a clear relationship between access to safe drinking water and public health: the lower the access to water, the higher the potential for ill health. Indeed, as noted in Chapter 1, development economists have introduced the term water deprivation – “the inability reliably to obtain water of adequate quantity and quality to sustain health and livelihood” – as a basic index of poverty (see Table 2.3 above).

Globally, water for domestic purposes accounts for 9 percent of total water withdrawals, although this varies by region from 5 to 15 percent (see Table 2.4). Withdrawals for domestic use vary widely by region (driven primarily by service level) with a global per capita average of 148 litres/day. Sub-Saharan Africa has the lowest per capita average at 41 litres/day and OECD countries the highest at 422 litres/day. Domestic use in relation to other human consumptive uses is proportionally higher in OECD countries (15 percent of total water uses) and Latin America (12 percent), whilst Asia, with much larger agricultural withdrawals, uses only 5 percent of its water withdrawals for domestic use.

It is worth bearing in mind that the absolute amount of water withdrawn and used for domestic purposes is relatively minor as a proportion of overall human consumptive uses and the total water resource base. The majority of human water consumption goes towards agriculture and industry.

3.2.2. Industrial use

Industries use water to transport both inputs and outputs, to cool industrial machinery (water is the most efficient means to lower a machine’s temperature), to produce energy, to make products and to clean and wash machinery and goods; it is also used as a solvent and as a part of the goods produced. Industries and commercial establishments also require water for their air conditioning. Cooling accounts for up to 70 percent of water use in industry. Power generation accounts for most of the water that industries use, due to the massive amounts of water needed to cool assemblies.

Table 2.4 - Withdrawals of (Blue) Water for Domestic Use, by Region/Grouping (1995–2000)

Region/ Grouping	Popula- tion (billions)	Total Domestic Water Use (km ³ /yr)	Domes- tic Use as % of Total With- drawal	Daily Domestic Water Use (litres/ capita/day)	% of Global Average
Asia	3.23	80	5	68	46
Former Soviet Union	0.29	34	10	323	218
Latin America	0.51	33	12	177	120
North Africa/ Middle East	0.40	22	8	153	103
Sub-Saharan Africa	0.67	10	10	41	28
OECD	0.97	149	15	422	284
GRAND TOTAL	6.06	328	9	148	100

Source: Vörösmarty *et al.*, 2005.

Forty percent of the water withdrawn for industrial use comes from groundwater (WWAP, 2003). The volume of industrial water withdrawal varies across regions, sectors, manufacturers and factories. The quality of the good produced and the technology employed in the manufacturing process affect the volume of water used. In addition to water withdrawal, industries often dump industrial by-products into nearby water bodies, sometimes using surface and groundwater systems as receptacles for the pollution and waste generated by industrial activities.

Globally, just over one-fifth of water withdrawals are for industrial purposes – roughly twice domestic uses (see Table 2.5). Not surprisingly, industrialized countries, including the OECD countries and the former Soviet Union, withdraw a much higher per capita rate of water for industrial use than do developing regions.

Table 2.5 - Withdrawals of (Blue) Water for Industrial Use, by Region/Grouping (1995–2000)

Region/ Grouping	Total Industrial Water Use (km ³ /yr)	Industrial Use as % of Total Withdrawal	Daily Industrial Water Use (litres/capita/day)	% of Global Average
Asia	99	6	84	25
Former Soviet Union	115	34	1 094	321
Latin America	31	12	167	49
North Africa Middle East	15	5	104	31
Sub-Saharan Africa	4	4	16	5
OECD	489	48	1 384	407
GRAND TOTAL	753	21	340	100

Source: Vörösmarty *et al.*, 2005.

3.2.3. Water in agriculture

Agriculture, including animal husbandry, is the largest human consumptive use of freshwater. Worldwide, about 70 percent of abstracted freshwater is diverted for agricultural irrigation. Irrigation is considered highly productive in terms of food produced per unit of land: 7 percent of the world's cultivated land is supported by human-made irrigation systems, and this produces 40 percent of the world's total food supply. Much of the dramatic increase in food production of recent decades has required high-yielding plant varieties (combined with fertilizers and pest control) that rely on irrigation that ensures an adequate and timely supply of water. Part of the water withdrawn for irrigation is used for crop production, and part is used to flush salts out of the soil to prevent a reduction in soil fertility over time. Of total agricultural irrigation withdrawals, 20 percent is estimated to come from groundwater pumping (WWAP, 2003) (see Table 2.6).

Some agriculture is supported by naturally occurring water flow alone. According to one estimate, rain-fed agriculture and permanent grazing are

responsible for the consumption of 25 400 km³/yr of freshwater (Falkenmark and Rockström, 2004). The natural flow of the water cycle produces about 60 percent of the world's food supply and supports a range of additional ecosystem uses, particularly in grass and rangeland areas where livestock is just one of many species taking advantage of the feed, water and landscape.

World water withdrawals for irrigation have increased by over 60 percent since 1960 (UNSD, 1999). This trend is expected to continue, particularly in countries with a high rate of population growth. Water withdrawals for irrigation do not vary as markedly from region to region as do domestic and industrial water use. The exception is Sub-Saharan Africa, where withdrawals are just 339 litres/capita/day, roughly one-third of the global average.

Table 2.6 - Withdrawals of (Blue) Water for Irrigation, by Region/Grouping (1995–2000)

Region/ Grouping	Total Irrigation Use (km³/yr)	Irrigation Use as % of Total Withdrawal	Daily Irrigation Use (litres/capita/day)	% of Global Average
Asia	1373	89	1 165	104
Former Soviet Union	188	56	1 788	160
Latin America	205	76	1 101	98
North Africa Middle East	247	87	1 713	153
Sub-Saharan Africa	83	86	339	30
OECD	384	38	1 087	97
GRAND TOTAL	2 480	70	1 121	100

Source: Vörösmarty *et al.*, 2005.

As currently practised, irrigation is not nearly as efficient as it could be. In certain instances, as a result of unlined canals or leakage from pipes, much of the water diverted for irrigation does not reach the intended crops.

Unchecked water evaporation also contributes to irrigation inefficiencies. Currently, more than half of irrigation water returns to river basins and to groundwater aquifers, but its quality has been degraded by pesticides, fertilizers and salination. With modern engineering and water technologies – such as the use of water sprinklers or drip irrigation – a considerable amount of water can be conserved. These methods can help increase crop productivity (by ensuring that water reaches each plant) whilst decreasing the volume of abstracted water.

Water used for irrigation and other agricultural uses does not need to be of the same quality as water used for domestic purposes. Treated wastewater can be used safely to irrigate agricultural land: growing plants can process the organic substances found in sewage and treated wastewater. Moreover, some of the nutrients found in wastewater support plant growth. It is necessary to ensure, however, that heavy metals are not also present in the treated waste. The risks for human health must be balanced against the benefits of wastewater use (see Chapter 8).

3.3. Human non-consumptive uses

3.3.1. Inland capture fisheries and aquaculture

Inland fisheries consist of capture fisheries (fishing) and aquaculture (fish farming). The value of inland fisheries is often underestimated. Developing countries depend on inland fisheries for food security, nutrition, income and livelihoods, especially in rural areas. The catch from inland fisheries provides almost 12 percent of total fish consumed by humans and, in many countries, freshwater fish make up the majority of total animal protein intake, particularly among the poor (FAO, 1999). Freshwater fish also provide vitamins and minerals essential to the human diet. Fish farming's role as a source of food and income, in both developed and developing countries, is increasing in importance, partially in response to the growing global crisis in marine capture fisheries. In developed countries, where food security is less of an issue, sport fishing plays a significant economic role, generating income, affecting water resource use and driving demand to restore and rehabilitate fish habitats.

Both the quantity and the quality of fresh water must be maintained to sustain inland fisheries. In fisheries, “quantity” refers to the area of aquatic habitats and the physical volume of water, whereas “quality” refers to water chemistry

and the quality of aquatic habitats, including the surrounding catchment and vegetation. Inland fisheries are biologically diverse in different parts of the world, but they all depend on a healthy environment and are influenced greatly by environmental changes.

Water for inland fisheries or aquaculture may be naturally available, as in lakes or rivers, or made available (abstracted) through the construction of reservoirs and other artificial fish habitats. Whether human-made or natural, water is “consumed” in lakes and reservoirs by evaporation (760 km³/yr) and changes in water quality. Freshwater management strategies must explicitly incorporate inland fisheries – and the lakes and reservoirs in which they are located – into their planning and consider fisheries managers and fishing communities as stakeholders in multi-use strategies.

3.3.2. Hydropower

Hydropower is the use of the potential energy in surface waters to generate electricity and create energy. Hydropower generation is an important use of water in many countries. Although water is not “consumed” in the strict sense by hydropower facilities, it is usually stored in reservoirs that affect the timing of river flows and can alter downstream flow and volume.

Hydropower facilities are divided into “run-of-river” and “storage” facilities. In a run-of-river system, the force of the river current applies the needed pressure. Run-of-river projects depend on river flows and are affected by seasonal flows and hydrology. Run-of-river facilities come in two types: diversion or barrage. A diversion run-of-river hydropower project harnesses the natural gravity from the river flow to produce electricity. It does not require an impounding dam with a large reservoir. Diversion run-of-river projects have four major components: a diversion weir, a pond or other mechanism that removes sediment from diverted water, a high pressure tunnel through which the water travels and the power plant itself. Water is then discharged either much lower in same river system or into a different system.

Barrage run-of-river facilities do not divert water from the river. Instead, they rely on a dam (called a barrage), which backs water up to achieve a greater height from which to harness potential energy. Water is not stored in this system; the incoming flow never stops moving through, over or around the facility.

In a storage system, water is stored in dam-created reservoirs, which then release the water when the demand for electricity is high. Storage facilities consist of a dam, a powerhouse with turbines and generators and a tailrace for returning water to the river. Depending on inflow and storage capacity, such plants can store and release water on a daily, annual or other basis. Storage facilities store water when electricity is less valuable (off-peak) and release water for power when it is needed most (peak). Some facilities also use “excess” energy at off-peak periods to pump water up into a reservoir in order to generate hydropower at later peak periods.

3.3.3. Navigation

For hundreds of years, humankind has been using the paths of natural rivers and also creating waterways for navigation. This involves diverting water for canals, creating channels, dredging rivers and building locks and other structures to facilitate the use of waterways for transport. Rivers are an important means of moving goods and people across distances, in both developing and developed countries.

3.3.4. Recreation

Freshwater bodies are often used for recreational purposes such as boating, rafting, kayaking, swimming and sport fishing. Many of these activities are central attractions of the tourist industry, which has the potential to generate local and national economic growth. Because these activities call for certain water quantity and quality requirements, the demands posed by recreational uses should be considered when formulating water and environmental management policies.

3.4. Ecosystem and biodiversity uses

Water is integral to the earth’s ecology and biodiversity. A wide range of ecosystems are based on and depend on rivers, lakes and wetlands; ecosystems require water to function and to exist. Freshwater-dependent ecosystems – such as mangroves, inter-tidal zones and estuaries – sustain millions of plant and animal species. Effective management of an ecosystem’s ecological functions requires addressing the full range of physical, chemical and biological demands of a healthy ecosystem.

Ecosystems provide myriad benefits and services that both directly and indirectly support economic activity and contribute to human welfare. Direct ecosystem services include human consumption of fuel, food, fibre, water and other natural resources from the ecosystem. Ecosystems also provide indirect services that support human welfare: they regulate the atmosphere and climate; purify and retain freshwater; form and enrich the soil; cycle nutrients; detoxify and re-circulate waste; and pollinate crops. Freshwater ecosystems support and provide for all of these needs, as well as others that enhance biodiversity, sustain animal and plant species and improve the human quality of life. A purely market approach to water management may not consider these non-monetized benefits, yet they unquestionably provide great value.

Box 2.3 - Freshwater Ecosystem Services

Provisioning services

- Water (quantity and quality) for consumptive use (for drinking, domestic use and agriculture and industrial use)
- Water for non-consumptive use (for generating power and transport/navigation)
- Aquatic organisms for food and medicines

Regulatory services

- Maintenance of water quality (natural filtration and water treatment)
- Buffering of flood flows, erosion control through water/land interactions and flood control infrastructure

Cultural services

- Recreation (river rafting, kayaking, hiking and sport fishing)
- Tourism (river viewing)
- Existence values (personal satisfaction from free-flowing rivers)

Supporting services

- Role in nutrient cycling (role in maintenance of flood plain fertility), primary production
- Predator/prey relationships and ecosystem resilience

Source: Adapted from Aylward *et al.*, 2005.

Freshwater and the hydrological cycle sustain inland water ecosystems, including rivers, lakes and wetlands. The Millennium Ecosystem Assessment (MA) was launched by the United Nations in 2001 to examine the consequences of ecosystem change for human well-being and to evaluate the state of scientific knowledge of ecosystem conservation. The MA provides a framework for classifying ecosystem services, in which freshwater is a “provisioning” service – providing for humanity’s domestic, agricultural, energy and transportation needs. In the MA lexicon, ecosystems also provide “regulating”, “cultural” and “supporting” services that directly and indirectly contribute to human well-being. Box 2.3 sets out the types of services provided by freshwater ecosystems.

A drawback of the MA lexicon is that it does not distinguish between the natural and human-made components of ecosystem services. However, it does encompass all the potential uses of freshwater and is therefore a useful tool to highlight the challenges society faces in choosing how to enhance or protect the range of services provided by water resources.

3.5. Balancing ecosystem protection and water resources development

The need to maintain ecosystem health is grounded both in ethics and in the practical benefits ecosystem goods and services provide to humans (UNSD, 1999; MA, 2003; UNECE, 2006). As a result of the growing attention given to the benefits of ecosystem services, increasing priority has been given to ecosystem requirements, or “environmental flows”, in water management decisions (UNSD, 1999). Too often there had been an over-emphasis on the benefits of water resource development to humans, without considering the impacts of these efforts on ecosystems or the complicated inter-relationship between water management and ecosystem health (WCD, 2000; Aylward *et al.*, 2005).

Over time, water management practices have increasingly focused on developing surface water and groundwater resources through investment in physical infrastructure, so-called “built capital”, such as dams, canals, wells and power plants rather than through the “natural capital” and ecosystem services of flood control or water quality provided by wetlands and flood plains. Built capital necessarily affects ecosystem health. A key issue for water management professionals is how best to balance human water needs with

ecosystem needs. Understanding ecosystem water requirements – and thus defining the “supply” needed by ecosystems – is a challenge.

Society may need to choose which natural resources and ecosystem services to take advantage of. For example, a town that relies on clean water that is naturally filtered by a heavily forested watershed may need to choose between the livelihood and economic benefits of logging the forest versus the naturally occurring clean water. In this example, foresters and water resource professionals must collaborate to assess and make choices regarding the impacts of logging and the costs of water treatment. Ecosystem service professionals need to clarify the tradeoffs between different “services” provided by natural resources and the resulting effects on human welfare and ecosystem health if those natural resources are used. In such instances, parties may be able to craft a “win-win” solution where logging continues in the watershed but is conducted in a manner and on a scale that preserves the ecosystem service of water purification.

In regions where there has been little development of water resources, the challenge is how to balance protecting and capitalizing on free or low cost naturally occurring ecosystem services with the potential to develop human-made services to provide for human water needs. In regions where heavy investment in water management infrastructure has already occurred, the water management challenge is often how to recover the welfare-enhancing ecosystem services that have been degraded without unnecessarily imperilling the water supply benefits of development.

When making water management decisions, it may be constructive to evaluate the costs and benefits of each alternative, choosing the level of ecosystem protection and water resources development that optimizes human welfare whilst creating the fewest adverse impacts on ecosystem health. It is not always possible to do so using monetary values, particularly for public goods. As a result, the tradeoffs between the many types of services are often very difficult to calculate in a common currency. At the same time, it may still be better to have a mix of monetary estimates and biophysical measures than no measure of ecosystem service provision at all (i.e. a value of zero), which is clearly incorrect.

IV. FRESHWATER AVAILABILITY, ALLOCATION AND PRODUCTIVITY

A comprehensive analysis of the sources and uses of freshwater is integral to future water resources management, but it can prove difficult. Most efforts to date have focused purely on withdrawals from groundwater and water bodies. Increasingly, water management professionals are using a more holistic approach that takes into consideration the totality of terrestrial precipitation and accounts for both blue and green flows (Falkenmark and Rockström, 2004). These analyses are being undertaken to better project future water scarcity and to determine how best to fulfil human and ecosystem water needs as the world's population grows. The blue and green water approaches are reviewed in the next sections.

Table 2.7 - Total Withdrawals of (Blue) Water, by Region/Grouping (1995–2000)

Region/ Grouping	Popula- tion (billions)	Total With- drawal (km ³ / yr)	Total Daily With- drawal (litres/ capita/ day)	% of Global Aver- age	Access- ible Water (km ³ /yr)	Use Relative to Access- ible Supply
Asia	3.23	1550	1 315	82	9 300	17
Former Soviet Union	0.29	337	3 206	199	1 800	19
Latin America	0.51	269	1 445	90	8 700	3
North Africa Middle East	0.40	284	1 970	123	240	118
Sub-Saharan Africa	0.67	97	397	25	4 100	2
OECD	0.97	1020	2 887	180	5 600	18
GRAND TOTAL	6.06	3557	1 608	100	29 740	12

Source: Vörösmarty *et al.*, 2005.

4.1. Blue water

Recall that water that moves through evapotranspiration is often referred to as green water (in that it cycles largely through plants), whereas freshwater discharged from river basins is referred to as blue water. As part of the Millennium Ecosystem Assessment, scientists calculated that of the 40 000 km³/yr of blue water flow available, only 30 000 km³ (or 75 percent) is accessible to humans in downstream areas (Vörösmarty *et al.*, 2005). Total withdrawal is estimated at 3 600 km³/yr, or 12 percent of the accessible flow. However, withdrawal varies tremendously by region. The Middle East and North Africa use 118 percent of their renewable supply, meaning that they use 100 percent of their blue water flows and are actively drawing from groundwater stocks – depleting them, potentially permanently. Asia, OECD countries and the former Soviet Union use between 15 and 20 percent of their accessible supply, whilst Sub-Saharan Africa and Latin America withdraw only 2 to 3 percent of theirs (see Table 2.7).

Despite the apparent availability of freshwater, a significant portion of these withdrawals may be locally unsustainable. Localized areas of water stress (the population is high relative to supply) and water crowding (water use is intensive relative to supply) may contribute to regional water shortages. Indicators of water scarcity for human purposes also suggest that there are increasing water shortages relative to the needs of aquatic ecosystems, particularly given that few countries provide protection for instream flows. Moreover, these estimates do not account for the accompanying degradation of water quality, which affects the utility of remaining flows for human and ecosystem uses. (See Chapter 6.)

4.2. Green water

An alternative formulation considers green water flows in addition to blue. This analysis considers the full terrestrial water cycle as the resource base with which to meet human and ecosystem water needs. It distinguishes between water consumed directly for human needs and water that contributes more to ecosystem needs, which may or may not indirectly provide additional services to humans.

Falkenmark and Rockström (2004) estimate that direct human uses of water are on the order of 28 500 km³/yr, after including evapotranspiration from rain-fed agriculture and livestock grazing (see Table 2.8). Nearly twice this

amount goes to indirect human and ecosystem uses. Humans use just a part of total blue water flows, with the bulk of blue water going to ecosystem maintenance. The authors conclude that current human consumption (3 100 km³/yr) and the amount of stable river flow that goes undiverted (9 400 km³/yr) suggest that 12 500 km³/yr is currently available for human uses, without the need to construct more storage reservoirs. It must be kept in mind, of course, that diverting water can have ecological costs as well, depending on how much water is returned to the ecosystem and its quality.

Table 2.8 - Global Water Balance for Blue and Green Flows

		Consumptive Use of Freshwater (km ³ /yr)		
		Direct Human Use	Ecosystem Use and Indirect Human Use	Totals
Blue Flow				
Direct	Irrigation	1 800		1 800
	Domestic and industrial	1 300		1,300
Indirect	Stable		9 400	9 400
	Flood flows		30 150	30 150
<i>Subtotal Blue Flow</i>		<i>3 100</i>	<i>39 550</i>	<i>42 650</i>
Green Flow				
Direct	Crops	5 000		5 000
	Grazing	20 400		20 400
Indirect	Grasslands		12 100	12 100
	Forests		19 700	19 700
	Arid lands		5 700	5 700
	Wetlands		1 400	1 400
	Lake evaporation		600	600
	Reservoirs		160	160
	Urban		100	100
	Unaccounted for			5 690
<i>Subtotal Green Flow</i>		<i>25 400</i>	<i>39 760</i>	<i>70 850</i>
GRAND TOTAL			79 310	113 500

Source: Falkenmark and Rockström, 2004.

Using available data, Falkenmark and Rockström estimate future needs for a planet expected to have nine billion people by mid-century. In order to adequately feed this population, an increase in consumptive water use of 5 600 km³/yr is expected. One of the most significant variables in this projection is growth in per capita meat consumption as incomes rise, since a much larger amount of water is required to produce meat than crops, as noted in Chapter 1. Falkenmark and Rockström project that in the future, food will be supplied from expansion of rain-fed agriculture in savannah areas rather than from increased irrigation of existing areas. In total, they project that the new requirements will draw 800 km³/yr from blue sources and 4 800 km³/yr from green sources.

The authors conclude that there remains considerable room to reallocate green water that ecosystems presently use, in order to expand agriculture into arable lands not currently devoted to food production. In other words, future food needs need not be met just from blue water flows, but from green water flows as well. Just as with blue water, green water uses can be made more efficient by moving green water from waste (pure evaporation) or ecosystem use to human use for food production. At the same time, to ensure a healthy ecosystem and a reliable flow of valuable ecosystem services, care must be taken to ensure that sufficient water remains accessible for environmental needs.

V. WATER RESOURCES MANAGEMENT

Water management consists of allocation, distribution and conservation decisions for water resources. Making these decisions requires addressing present challenges whilst preparing for future ones.

5.1. Water management and its challenges

For freshwater, the water cycle can be divided into three components: what happens from the ground up, what happens below the ground and what happens in surface waters. Water management can therefore be grouped into: (1) watershed management; (2) groundwater management; and (3) surface water management. The quantity and quality of water stocks and flows are affected by a range of land use and water management decisions. For example, vegetation management can affect precipitation and runoff whilst watershed management can affect evapotranspiration, infiltration and soil moisture. Similarly, the level of the water table is affected by the rate of percolation and groundwater extraction. Direct interventions in surface

water bodies (such as diversions, abstractions and water storage) can affect runoff and return flows from groundwater. Accordingly, several key issues must be borne in mind when making water management decisions.

First, water resources must be managed at the appropriate scale. For watershed and surface waters, the watershed is the appropriate management unit. By contrast, the appropriate management unit for groundwater is the aquifer. Second, water management issues and responses may take place at different hydrologic levels, since some watersheds lie within each other and are connected through upstream-downstream interactions. The issues that arise or the effects of management responses at one part of the water cycle may or may not have effects at others. For example, changes in land use in a headwater area may affect flood flows immediately downstream, with important consequences for land owners or people who make their livelihoods in the immediate area. Further downstream in the basin, however, the impacts are likely to be attenuated or reduced, as streams draining other headwater areas converge, each with its own distinct flood peak based on watershed hydrology and the timing of precipitation (for example, as a storm moves across the basin). Understanding the relationships amongst watershed function, groundwater recharge and discharge, as well as surface flow patterns across the extent of a watershed or basin, is important for effective water planning and management.

Finally, water management needs to be integrated in the temporal dimension. Although some water moves through the water cycle over a course of weeks or years, other water, particularly groundwater, has a much longer cycle which may be measured in hundreds or thousands of years. Water management must therefore recognize that different components of the system react at different time scales.

In the past, water resources management primarily focused on making water available. Today, the focus is increasingly on maximizing water's overall productivity (rather than merely water supply or efficiency) and acknowledging water's dual role in providing for both human and ecosystem needs (Molden and Falkenmark, 2003). As the world population grows and the climate changes, water will continue to grow scarce in areas where water resources are already crowded and stressed, and water scarcity will emerge in areas where water is now plentiful. Data suggests that there is enough water available for human and ecosystem needs. The main constraints on water availability are quantity, timing and quality. Water will continue to be

plentiful, but may not be in the necessary location at the necessary times to adequately serve human and ecosystem needs. Addressing this challenge lies at the foundation of water resources management.

Given the variety and scale of competing uses for water – domestic, industrial, agricultural and environmental – moving water to where it is needed is inescapably a mix of economics, engineering and socio-political concerns. Moreover, the management of water resources is often linked to other environmental and resource issues, such as climate change. It may be possible to mitigate climate change through conservation of existing forests, reforestation of degraded forests or afforestation. However, forests have high rates of evapotranspiration. Planting forests for wood and carbon increases the amount of green water used by forests which, in some circumstances, could reduce the green water available for food production, possibly depleting groundwater and surface water stores as well. It is thus essential to look at land and water management simultaneously.

5.2. Integrated water resources management

Water management professionals are increasingly using a methodology called integrated water resources management (IWRM) (or integrated river basin management) to best address and balance these issues. The Global Water Partnership (a joint initiative of the World Bank, the United Nations Development Programme and the Swedish International Development Cooperation Agency) has defined IWRM as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2007).

IWRM requires effective frameworks for the cooperation of all interested stakeholders. The fundamental goals of IWRM depend on harmonizing the institutional frameworks for water management and promoting the participation of water users. IWRM will only succeed if it is a multi-disciplinary undertaking that uses all available knowledge and experience, both scientific and traditional. Successful IWRM also depends on a supporting policy, legal and regulatory environment. The legislative framework is the subject of the next chapter, whilst IWRM is discussed in greater detail in Chapter 6.

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WATER GOVERNANCE: POLICY AND LEGAL FRAMEWORKS *

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Good governance is essential to effective water management. Although some countries face genuine water scarcity, in many countries the roots of many water management problems lie in poor governance. As a United Nations Development Programme report has bluntly stated, “power, poverty and inequality” are far more to blame for water management problems than physical availability (UNDP, 2006). Improved water governance coupled with effective policies will be critical to managing the world’s freshwater resources and avoiding a water crisis (UNDESA, 2003).

The primary tools with which public authorities govern water and implement policy are national laws, regulations and standards. This chapter examines these tools and sets the context for the water management strategies examined in later chapters. The first section introduces the concept of water governance, followed by an introduction to water policy. The remaining sections of the chapter outline how to evaluate current water laws and create strong legislative frameworks that can more effectively implement national water policy whilst addressing the challenges facing water resources management and water services provision.

I. WATER GOVERNANCE AND WATER POLICY

1.1. Governance

The systems that develop and manage water resources and water services delivery fall under the broad umbrella term of “governance” – an evolving concept without a universally accepted definition. Governance is perhaps best understood as the “exercise of economic, political and administrative authority to manage a country’s affairs at all levels” (UNDESA, 2003). Governance specifically concerns the “political and administrative elements of solving a problem or exploiting an opportunity” (Rogers and Hall, 2003) and broadly encompasses tools such as laws and regulations, economic instruments, public expenditure and any other initiatives a government uses to implement its decisions (UNDESA, 2006). Effective governance results in improved development and human well-being – higher per capita income, higher literacy rates, lower infant mortality rates and reduced poverty, amongst others (Rogers and Hall, 2003).

Water governance has not always been recognized as important. The connection between governance and management first received wide recognition in 2000 at the Second World Water Forum in The Hague, where members of the international community specifically acknowledged the

significance of water governance and its key elements: ownership, development and management of water resources. At the Forum, leaders identified “governing water wisely” as the principal challenge for water resource management.

The United Nations has established several criteria against which decision-makers and policy-makers may evaluate their policies, laws and management decisions to determine whether they create an effective governance model (UNDESA, 2003):

- the system encourages *participation* of all citizens;
- decisions are *transparent* and open to public scrutiny;
- all groups in society have *equitable* access to water to improve their well-being;
- all organizations (whether governmental or non-governmental) and the private sector are *accountable* to the public;
- government policies and actions are *coherent* and understandable;
- water institutions are *responsive* to stakeholders’ needs and demands;
- water governance is *integrative*; and
- the governance system is “based on the *ethical principles* of the societies on which it functions” (UNDESA, 2003).

In view of increasing global water scarcity and the emergence of new technologies, many countries have already begun to assess and transform their water governance structures. Although each nation’s reforms vary, the efforts share common elements. Most reforms decentralize decision-making; increase stakeholder participation in water management decisions; promote and improve public/private partnerships; incorporate principles of integrated water resources management (or integrated river basin management); and clarify institutional roles and responsibilities through formal legislation and informal customary water rights (UNDP, 2006).

Specific national goals for governance reform vary according to a number of factors, including a nation’s level of development and industrialization. Developed countries often have a more established rule of law – i.e. national laws and regulations are more rigorously implemented and enforced – as well as the political will, administrative authority and resources necessary to change the governance structures. On the other hand, developing nations often have more flexibility to overhaul water laws and policies in their entirety and re-draft them according to current needs and emerging trends. As will be emphasized

throughout this book, each country has a unique combination of geography, resources, history, laws and needs for economic growth. Thus, each government must determine what works best in its particular circumstances.

1.2. Policy

Broadly speaking, water governance is carried out through water policies for the administration and management of water uses. Policies may be national, international or local, although this chapter focuses mainly on the national ones. National policies reflect a country's values and objectives, determining the laws and other strategies that the government uses to implement its goals. A policy may consist of broad social objectives – such as ensuring universal access to water – or narrower objectives for mitigating specific problems, such as decentralizing water management for greater efficiency. Policies often focus on long-term objectives and act as a framework for future government actions.

Due to the complex nature of water systems, water policies are generally most effective when they are created within a larger, inter-disciplinary framework that includes economic, social and natural resources management concerns (see Salman and Bradlow, 2005; FAO, 1995c). Important objectives for water policies may include integrating the management of water and land; defining goals for the different water sectors; creating procedures for identifying, measuring, presenting and evaluating the costs and benefits of development projects; and designing long-term use strategies for each sector and river basin, including conservation strategies (see Salman and Bradlow, 2005).

Since the Rio Declaration on Environment and Development, which was adopted at the United Nations Conference of the same name in 1992, the international community has embraced a sustainable development agenda. Accordingly, nations have committed to ensuring that economic and social development are accompanied by environmental protection measures. Good water policy should therefore give equal consideration to water not only as an economic but also a social and environmental “good”.

Since national circumstances and technologies change over time, policies should also be dynamic. They must be flexible enough to address current national and international issues and government's evolving objectives, although not so malleable that they change too often, causing uncertainty amongst the regulated community (FAO, 1995c). Importantly, as new policies are created or current policies amended, existing laws and initiatives must also be reviewed to ensure consistency and harmonization at national level.

Although water policies are unique to each country, successful policy development shares common features. After establishing its policy, a government must craft strategies to bring the policy to fruition. Such strategies may consist of legal tools (such as laws and regulations), economic tools (such as taxes or tax deductions) and other means (such as education and awareness-raising initiatives). These building blocks of water governance are described below.

II. LEGAL FRAMEWORK FOR WATER

2.1. National and international overview

The primary tool to implement policy is legislation, i.e. laws and regulations. Legislation, like policy, can exist at different levels of government: local/municipal, regional/provincial, national and international. As a general matter, laws set forth rights, obligations and institutional roles. They also establish a broad framework for more detailed requirements elaborated in subsequent subsidiary instruments such as ministerial regulations. Within a country, the Constitution or national laws generally set out the substantive boundaries of what regional or local governments may legislate on. This will vary depending on the country's legal system and legal traditions.

The two most common legal systems are common law and civil law. Common law regimes draw from the Anglo-Saxon legal tradition. Laws may initially start with the legislature but the corpus of law is mainly developed through court cases and judicially created doctrines. Courts follow *stare decisis*, meaning that judges follow precedent (prior judicial decisions and the decisions of higher courts). Common law countries also have statutory laws, and courts play an important role in interpreting both codified laws and non-codified legal doctrines. Civil law countries, by contrast, have long had codified laws, mainly descended from or influenced by the early Napoleonic Code. Courts in these countries generally play a less important role in legal interpretation. Customary laws, laws derived from the customs and habits of the people, are prevalent in both common law and civil law countries.

In addition to national laws, most countries are subject to a variety of international obligations. There are four sources of "international law": treaties, customary laws, general principles and judicial opinions.

- *International treaties* and other binding obligations take effect upon ratification by a designated number of nations, and those nations must honour the signed agreements.
- *International customary law* emerges from the consistent conduct of multiple states. A marker of customary international law is consensus among states, exhibited both by widespread conduct and a sense of legal obligation to act in a certain way. In other words, customary law derives power from the customs and practices that states recognize as obligatory.
- *General principles of international law* are principles common to the domestic laws of many nations, and when neither a customary law nor a conventional law covers a particular legal issue, these principles may come into effect.
- *Judicial opinions* applicable to international law include judgments and advisory opinions of international courts, awards rendered by arbitral tribunals and decisions by national tribunals.

It is important to note that international law derives its power from the consent of the sovereign, signatory nations and often has no monitoring or enforcement mechanisms. International law and its instruments as they relate to water will be described further in Chapter 4.

2.2. Traditional and evolving approaches

National water legislation has often distinguished between different water resource sectors without considering their inter-connectedness. For example, water pollution is affected by water quantity (as greater river flows dilute pollution concentrations), and yet pollution control is often regulated and managed separately from water allocation. Similarly, groundwater levels affect surface water systems and yet groundwater is often regulated without consideration for the surface water systems to which the groundwater sources are often linked. By the same token, some water sources, such as springs, exhibit features of both groundwater and surface water and so may be duplicatively regulated or not regulated at all.

Despite these hydrological realities, in many nations separate laws deal with surface waters, groundwater, water resources abstraction, water pollution, irrigation and drinking water. As a result, water-related provisions are often scattered throughout a wide range of laws, regulations or decrees. The legal framework for water may have overlaps, duplications of responsibility among

various authorities, ambiguities and gaps in coverage – grey areas left unregulated in the absence of a specific law, or fragmented policy areas that are ignored or under-emphasized. Moreover, laws may skew policies, for example protecting surface water at the expense of groundwater. Water laws should accommodate rather than ignore the realities of the water cycle.

In the past, many nations drafted their water policies and water laws under the assumption that water was inexhaustible. Accordingly, the existing framework may inadequately address the challenges of water scarcity and the need for sustainable water resource management. The legislative framework may not permit authorities to implement water policies that incorporate advances in knowledge and technology. Nor may the legislation allow government to play a more interventionist role aimed at ensuring fairness of resource allocation among users and an integrated approach to the development, management and conservation of water resources.

In an environment of greater scarcity and the need to balance competing uses, many governments are in the process of revising their national water legislation. Many circumstances and issues may drive reform of the national legislative framework for water. Jurisdictions may change their water laws after determining that water resource deficiencies were largely attributable to conflicts between sectors (Chile), in response to widespread frustration with government bureaucracy and unsupervised spending (State of Victoria, Australia), in order to address and resolve past injustices (South Africa) or to bring a new level of consistency of direction and purpose to water policies and provincial water programmes (Argentina). There are many other reasons as well.

In the process of revising their national legal frameworks for water, governments will have to assess and review a host of related legislation that has an impact on water resources management, such as legislation on land use, agriculture, forestry, biodiversity or species protection and air quality. Such a broad perspective is called for because of the nature of water flow: unwise land use and zoning can degrade water quality and wreak economic and social devastation on those living downstream; over-harvesting of forests may increase erosion and sedimentation; and air pollution may contain elements such as sulphur dioxide that cause acid rain, which leads to the acidification of lakes and ponds, or mercury which contaminates fish and eventually harms consumers.

Good water laws, rather than being fragmented across different sectors, address the full range of issues connected to the management, development,

use and protection of the resource. Many recent laws also directly address the regulation of water services and encompass management and planning, issues generally absent in traditional water laws. The only significant regulatory area that often continues to be regulated separately is the provision of water supply and sanitation services, due to its complexity and importance (see Chapter 7).

2.3. Features of good water laws

Good water legislation should reflect three main characteristics. It should be clear; it must provide secure rights; and it must contain enforcement mechanisms that are both adequate and feasible and that can be applied consistently. These features are reviewed in more detail below.

2.3.1. Simplicity and clarity

Although the argument that “laws should be simple” may be attractive, creating simple laws is not always possible or desirable. Unlike a policy document, a statute must follow a certain format to create binding obligations. Moreover, the hydrologic cycle is complex, as are the rules that govern it. Complicated laws and regulations are often perceived as pursuing arcane legal goals and ignoring the practicalities of implementation, but if all of the relevant issues are to be addressed comprehensively (including those related to health and development), water legislation may not be as simple as policy-makers might like. For example, the idea of “simplicity” was aired frequently during South Africa’s water policy review process, but the South African Water Act contains more than 100 pages of detailed provisions. Similarly, the 2000 Water Act of the Australian State of Queensland consists of some 1 100 sections and fills a 400-plus page book.

Nonetheless, law-makers should strive to make laws as basic as possible, leaving the details to implementing regulations which can be more easily changed. Rather than having to proceed through the lengthy legislative or law-making process, regulations are usually elaborated, issued and amended by a particular agency, ministry or department.

More critical than simplicity, however, is clarity. Regulated parties – as well as the regulators – must know what their legal obligations are. Laws must clearly describe the basic principles behind the legislation so that subsequent implementing regulations can build on the original intent of the law. The law must also clearly define the process and procedures for rule-making, including the degree of transparency and participation.

2.3.2. Security of rights

Water rights attempt to confer on the right-holder a degree of legal security which thereby promotes investment in the resource. Security of water rights is linked not only to water abstraction and use but also to wastewater disposal, since the right to use water implies that the water maintains a certain quality. Because the actions of upstream users have an impact on the quality and quantity of the water source and therefore affect downstream users, water legislation must strike a balance between the security needed to encourage investment and the need for administrative flexibility to re-allocate water resources from one use and user to another. Furthermore, since water availability can vary seasonally and from year to year, and since a water right can be exercised only if a source contains sufficient water, legislation should clarify whether government has the authority to curtail water rights during droughts or low-river flows or to accommodate a competing use. Licensing requirements for water abstraction and wastewater disposal should be structured so that they may be easily adapted to new circumstances, even in emergencies such as shortages or contamination. If properly designed, they should also permit changes to be made in less pressing circumstances, such as the need to accommodate technological advances in water management.

2.3.3. Implementation and enforceability

Implementation and enforcement issues are often left unaddressed during the preparation of legislation, which can severely undermine the law's efficacy. Failure to consider implementation issues may result not only in misallocation, over-exploitation or inequitable distribution of water, but also degradation of water resources. The government's administration and enforcement capacity, as well as users' capacity to comply with the new legislation, should be assessed during the drafting process and duly accounted for in the procedures set out in the law. The experiences of several countries reveal that considering implementation requirements while preparing new legislation improves the quality and realism of the legislation elaborated (FAO, 2001). The reverse also holds true, i.e. that lack of foresight regarding feasibility of execution can delay the implementation of new legislation.

Legislation must also resolve several questions regarding enforcement. First, who is subject to the law's restrictions? Second, the legislation must define which agencies and actors can enforce the law. Enforcement may be solely the obligation of government agencies – federal, provincial or local – or, as in some countries, the public may also enforce legislation directly through

“citizen suits”. Third, legislation needs to designate the correct forum for enforcement: do parties have to go through an administrative process, pursue mediation or arbitration or seek enforcement through the judicial system? Legislation must also designate the applicable appeals process. This is particularly important in federal republics where the proper appeals forum could be in state or federal court. Legislation must settle these questions to avoid confusion and allow for an efficient and just judicial process.

Finally, legislation should designate the proper remedies for violations. Remedies may include injunctions, restitution, fines, damages or imprisonment. An injunction is a court order stopping the violator from continuing the actions that are causing the violation, and may be temporary or permanent. Restitution orders the violator to restore the situation to its pre-injured state (e.g. cleaning a river into which wastewater was illegally dumped). Alternatively, restitution may require the violator to pay the equivalent of returning the water resources to their pre-injured state, for example where clean-up is not physically possible.

Fines and damages are both financial remedies, but their applicability depends on who is harmed. A fine is generally a remedy for violating a statute, and the proceeds go to the government (sometimes to help regulate and enforce the law, sometimes to the general treasury). Damages, by contrast, are awarded to an individual who has been injured by the violator’s neglect or misconduct. These may be personal harms, such as illness or injury, or property harm.

The most extreme remedy is imprisonment. Except in countries where all offences are set out in a Criminal Code, the water legislation should specify the degree of *mens rea* (mental state) that must have been present in the violator to result in imprisonment. In other words, what was the violator’s intent? Did he or she intend to cause the harm and knowingly violate the law, or was the damage caused by recklessness or negligence? For example, the United States’ Clean Water Act has a maximum imprisonment of 15 years depending on many factors, including whether the violation was negligent or intentional.

III. SUBSTANCE OF NATIONAL WATER LAWS

The remainder of this chapter focuses on water legislation, outlining how water is regulated and describing key elements of water laws. It introduces important areas of inquiry such as ownership of water and abstraction rights; environmental protection; administrative structures for water management; and regulation of drinking water.

The discussion is intended to provide an analytical model for use in assessing a country's national legal framework for water. Employing this analysis should assist jurisdictions in identifying strengths, weaknesses and gaps in their water laws, and in elaborating an integrated legislative framework that includes environmental and human health and development concerns. To see this analysis applied with respect to specific countries and to make comparisons among them, visit the online database of national water laws at www.waterlawandstandards.org, a system that was designed and implemented by FAO and WHO alongside the development of the present text.

After analysing the enumerated substantive areas of water laws, the chapter concludes with an examination of some other key issues of water legislation, including the role of customary law, market-based regulations and government institutions, and suggestions for incorporating planning, integrating environmental, ecosystem, health and development concerns into water legislation and, finally, involving water users.

3.1. Ownership or other status of water resources

Water resource ownership and water rights allocation are two essential and related aspects of water law. To identify the legal framework related to ownership of water resources, public rights to water and the importance of water relative to other natural resources, the first step is to determine whether water is addressed in the national Constitution or Bill of Rights and to identify all water-related statutes. The extent of the state's ownership and regulatory role may vary, ranging from outright state ownership (in some constitutions or statutes) to a less direct approach, such as the "public trust doctrine", which considers water the property of all and which the government holds as a guardian or trustee. Furthermore, state ownership or trusteeship may embrace all water resources or leave some under private ownership or control. For indigenous communities, the government may establish forms of communal ownership. The applicable approach or approaches to the ownership of water resources may be explicitly stated in the constitution or law or implicitly result from the structures that the legal framework establishes.

3.2. Abstraction of water

A fundamental role of water law is to provide a mechanism for allocation of the resource amongst competing users, regardless of whether water is held under public ownership, public trusteeship or state custodianship. A formal

allocation system gives water users some security that they will be able to access sufficient water to meet their needs, whilst maximizing the benefits of water across a certain region or country. A well-defined water rights system encourages responsible water use and facilitates sustainability of the resource.

Legislation may address whether the government will regulate the right to abstract water by granting licences (also referred to as permits or rights) and whether those rights are linked to land ownership. Under a licensing scheme, water may be allocated among diverse users and diverse water use sectors in accordance with the government's priorities and plans. Criteria for the grant of water abstraction licences represent the practical application of a government's environmental and public health priorities, amongst other concerns. The administering authority may prioritize use permits or licences based on a balance of societal, economic and ecological needs. Governments may wish, for example, to prioritize providing water for drinking, the environment, irrigation or industry, and must take steps to ensure that each water source can support these abstractions.

A state may consider a range of factors before granting water abstraction licences, such as the hydrology, the current and future demand for and availability of water and the likely impact the licensed use will have on water resources. The criteria employed to evaluate applications and grant or deny licences should be transparent, and should be applied to all applications in the same manner so as to ensure consistency and fairness.

An administrative structure should be in place to implement, monitor and enforce the system of water abstraction licences. Monitoring is particularly important for effective enforcement. For example, irrigation typically uses the greatest amount of water, and poorly managed irrigation schemes can over-abstract and inefficiently use water which may harm the ecosystems that also need the water. An effective monitoring system would evaluate how irrigation licence holders are using their water in order to make any needed changes. Where the licensing scheme allows for the suspension or variation of licences during their period of validity, the administering authority might suspend a valid existing licence and reallocate the water to another user where circumstances have changed or water needs and priorities in the region have shifted. Because such government action compromises the security of the licence holder's rights, the legislation needs to clarify which circumstances could lead to loss, suspension or variation and what compensation is payable, if any.

Water legislation may also identify uses that are exempt from water licensing requirements (such as household or stock water uses) and should provide for the recording of the water abstraction licences. The legislation should also indicate whether water abstraction licences are subject to specific terms and conditions. For example, licences may be issued subject to restrictions on the amount, rate or timing of abstractions or on the type of water use to which they apply. The administering authority may also impose time limitations on the licence period.

Water abstraction charges may help regulate use. If policy-makers choose this method of economic regulation, then legislation must clearly establish how charges will be calculated for the abstraction of water from streams, lakes, underground aquifers and other water bodies so that users can calculate their overall costs before proceeding. This is particularly important for businesses making investment decisions.

Legislation may provide that licences are tradeable, as this can foster efficiency in water allocation and use. However, it may also mean that water rights may not necessarily rest with those who will put the water resources to the best use. On the other hand, prohibiting water rights trading may cause water shortages, since once water supplies are fully allocated, new water users cannot easily be accommodated and existing users may have little incentive to conserve water. Economic development policies may be impaired if water cannot gravitate towards higher-value uses.

Finally, as demand for water increases, the hydraulic connection between surface water and groundwater must be taken into account. As groundwater is a particularly vulnerable resource subject to over-exploitation, it must be carefully managed. Legislation should regulate groundwater resource development, including prospecting (borehole drilling for groundwater exploration purposes). Furthermore, as surface water and groundwater approach full allocation, the legal regime may need to consider the right to capture rainwater. As rural land owners or urban dwellers install rainwater harvesting systems, these will have a greater impact on existing downstream water rights and users (see Chapter 9).

3.3. Environmental protection

Water legislation must address not only water quantity but also water quality. Starting with water pollution control, water legislation must address whether permission is required to directly or indirectly discharge effluents (waste

materials) into streams, lakes, underground aquifers and other water bodies. As with abstraction, legislation must clarify the criteria for considering applications and granting permits and mandate that written records be kept of permits to discharge waste.

Furthermore, water resources legislation must specify whether wastewater discharge permits are subject to any exceptions or any terms and conditions, including duration, and whether there are applicable standards for effluent or ambient water quality. Legislation should set out how any such standards are set and reviewed, and by whom.

Legislation should also address whether wastewater discharge permits are tradeable on the market; whether they can be revoked, suspended or varied during their period of validity (and if so under what circumstances and whether compensation is payable); whether “vested” rights for wastewater disposal activities will be protected when any new legislation takes effect (an issue that also arises with water abstraction licences); and whether the government has the authority to declare certain regions or areas subject to additional restrictions on wastewater discharge (for example, where there is a risk of contamination of a drinking water source) and the procedures for making such declarations.

Legislation on wastewater disposal should also establish a system to monitor and enforce permits, for example by levying charges for wastewater disposal into water bodies. Provisions to control pollution of water resources from “diffuse” sources – for example, from the drainage and runoff of cultivated land where nitrates are used – should also be addressed (see Chapter 6).

To ensure the greatest environmental protection, the legislative framework must effectively address the full range of water-related ecosystem needs. Legislation may do this by setting instream flow requirements; enforcing instream flows; setting up a regulatory framework for payments for watershed services; and providing incentives for conservation of resources. Each of these regulatory strategies is discussed below.

Setting minimum flow requirements. Legislation may account for the environment’s needs by setting a minimum necessary flow and then requiring maintenance of that minimum. However, maintenance of minimum flows often does not provide for a fully functioning ecosystem. As a result, increasing attention is being paid to defining environmental flows as a series of hydrological

parameters that permit variability through the years (and across years) to better mimic the natural hydrograph.

Enforcing instream flows. Countries that choose to maintain instream flows for environmental and recreational uses have several options. For those rivers that remain relatively wild and free-flowing, placing restrictions on infrastructure development and use may be sufficient. However, many rivers are already developed and the applicable water licences already allocated. Legislation must then account for ecosystem needs within an already existing allocation and licensing scheme, determining the needs of both the water users and the ecosystems that rely on water. Experience in many countries indicates that reaching an allocation that satisfies the competing uses can be politically challenging. It is therefore essential that ecosystems have a representative or that other legal safeguards ensure that ecosystem interests are defended during allocation decisions.

Regulating payments for watershed services. Watershed service payment schemes enable downstream beneficiaries to contract with upstream land owners for improved land use and land management practices. Such schemes can be an effective way to protect watersheds for drinking water, agriculture and ecosystems. A solid legal framework for the enforcement of contracts and land tenure, as well as strong government oversight, are important. If parties to a contract know that the legal system will support and uphold the contract terms, they will be more likely to enter into contracts and this can improve environmental protection.

Similarly, the greater security of land tenure in the region, the greater the likelihood that service payments will emerge. Watershed service payment schemes are also being implemented through legislation imposing a system of water charges on users of the resource, where the water charges explicitly incorporate an environmental services component. An example of this can be found in recent Costa Rican legislation (see Box 3.1).

Providing incentives for conserving resources. Incentives for conserving water generally involve pricing water so that more use results in higher cost to the user. Fees may be applied to domestic, agricultural and/or industrial uses. Other incentives for water conservation include tax reductions, tax credits or cash rebates to individuals and businesses that implement water conservation measures (such as by installing water conservation fixtures in homes or repairing irrigation canals).

Box 3.1 - Charging for Environmental Services in Costa Rica

Under a presidential decree of 2005 in Costa Rica (No. 32868), all concessions and authorizations for the abstraction and utilization of water resources – including those held by government institutions – are subject to a charge. Water charges include an environmental services component which reflects the cost of conserving, maintaining and restoring ecosystems and basins in areas of importance to the hydrological balance (such as protected state forests). Charges are calculated on a volumetric basis in accordance with the decree.

This charging scheme was designed for gradual implementation over a period of seven years. From the eighth year on, charges will be automatically adjusted for inflation. Half of the proceeds from the collection of water charges will be destined for the integrated management of water resources at the national level and for a number of projects. The remaining half will be earmarked for investment in the resource's basin-of-origin, and will be used for the conservation, maintenance and restoration of protected state forests, national parks, biological reserves and private property located inside state lands, in recognition of the environmental water protection services provided.

The balance will go into a National Forestry Fund, which will provide the necessary resources to finance the Environmental Services Payment Programme. This programme will compensate private land owners for the environmental service of protecting and conserving water resources – especially sources of drinking water in areas significant to water resource sustainability. Part of these funds can also go to municipalities to fund the purchase of private land to protect groundwater recharge areas and water sources of local importance. Public and private providers of drinking water supply services, irrigation and aquaculture water services and electricity services must reflect their water charges in the tariff structure of the services they provide. These transparent charges are borne by customers, who are the final beneficiaries of the environmental services.

Source: Burchi, 2006

3.4. Government water administration

Many water bodies extend across multiple national or sub-national jurisdictions. Accordingly, the legislative review should determine how

responsibilities are allocated at the national/federal level and at all subordinate levels of government, notably at the river basin level. For example, in countries with federal systems, the water resource management responsibilities of the states/provinces should be identified, as well as how water resource management powers are shared between the federal and state governments. Unclear allocation of authority increases the likelihood of ineffective governance.

In some cases, legislation may create a special-purpose governmental administration at the river basin level that cuts across jurisdictions. The administration may have its own responsibilities and structure in addition to, or in place of, those existing at the federal and state level. Legislation may also specify whether local governments have any responsibility in water resources management and whether the establishment of associations or other water user groups will be provided for and regulated.

3.5. Drinking water and water services

Water resources legislation should ensure sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses. However, because of the complexity of regulating drinking water provision and sanitation services, it is often regulated in separate legislation.

Legislation on drinking water should address both access and quality. It should clearly delineate roles and responsibilities of all parties, empowering authorities to manage drinking water from source to consumer, including surveillance for and response to potential drinking water contamination and water-borne illness events. Legislation may designate the minimum volume of water that must be provided for drinking water and may set explicit priorities ensuring that the highest-quality water resources are set aside and protected for that purpose. Legislation may identify responsibilities for setting water quality standards and establish guidelines for monitoring adherence to and enforcement of these, alongside penalties for non-compliance. Legislation should provide authority for third-party oversight and monitoring and should require public reporting by drinking water purveyors, public health professionals and other stakeholders to ensure accountability.

Legislation must establish controls over the state entities and private corporations that supply drinking water. Such controls should outline the responsibilities of suppliers both during normal operation and during emergencies. These controls normally also provide for licensing, certification and approval of chemicals and materials used in the treatment, filtration and

distribution of drinking water. Legislation may also provide for tariff structures and controls, including connection costs, water use charges, subsidies and mechanisms for dealing with non-payment of tariffs (see Chapter 7).

IV. OTHER KEY ISSUES IN THE LEGAL FRAMEWORK FOR WATER

4.1. Integrating customary law

Customary law plays an important role in water management in many countries, particularly at the community level. Like international customary law, local customary law develops from the traditions and norms of a certain society that come to be accepted as rules or law. These rules have often evolved over hundreds of years and may be best adapted to local water situations and cultural, social and livelihood practices. Customary water laws are rarely a single and unified body of rules and can vary widely from region to region, sometimes even between villages in the same region. Customary rules governing access to water have been documented in many countries, the best-known example perhaps being the allocation system of irrigation water and water rights on the island of Bali, Indonesia (Caponera and Nanni, 2007).

For most countries, the goal of revising water laws is to establish a formal system that will facilitate the most rational use of available water, guarantee access to safe water and support the administrative system governing water resources. A subsidiary goal in many countries is to replace and integrate existing traditional and customary systems. To that end, it is important that when establishing a formal water use regime (with its emphasis on legality and written rules), the new system does not penalize, harm or deprive water users who have relied on unwritten customary rights of water access and use. Otherwise, enforcement will prove challenging and often impossible.

One way to address customary rights in water legislation is simply to recognize them formally, for example by providing that traditional water rights shall apply so long as they do not conflict with written legislation. The 1994 Guinea Water Code, for instance, provides that customary rights of local communities are valid unless contrary to the provisions of the Water Code. The legal frameworks of Côte d'Ivoire, Namibia and Papua New Guinea establish similar accommodations and integrations of customary water law. Papua New Guinea's 1982 Water Resources Act states that customary water rights prevail over written law, and Namibia's Water Resources Management Act of 2004 explicitly acknowledges customary

water rights and practices. The Namibian Act, as well as the 1998 Water Code in Côte d'Ivoire, require a thorough consideration of customary rights in evaluating, assigning and licensing water rights.

Some legislation on groundwater integrates customary and written water law by recognizing, formalizing and compensating violations of customary rights. The rationale for this approach is that without sanction and compensation, modern groundwater development may destroy or impair traditional and indigenous water user rights (Solanes, 1999). Thus, for example, Papua New Guinea's Water Resources Act compensates customary rights if groundwater development affects them.

Some jurisdictions define and legalize customary laws through a registration scheme. In this way, unwritten rights are essentially transformed into written rights. For example, after enacting its 1984 Water Code, Cape Verde required that customary water rights be claimed and proven in front of the National Water Council within six months, after which the customary rights would be regulated according to the Water Code. Namibia's 2004 Water Act recognizes and protects customary rights and practices by imposing terms and conditions in the administration of water abstraction licences. The 1992 French Water Act requires registration of customary riparian rights in order to better regulate them in the future.

However, in some contexts mandating registration may have negative impacts on the poor – particularly women and indigenous peoples – who may not be able to successfully navigate complex formal administrative processes, reach government offices in urban centres, communicate in the official language of the state, complete the forms necessary to claim and formalize their water rights or even be aware that such measures are necessary. To protect against inequity, states implementing mandatory registration schemes should establish effective notification procedures to ensure public awareness, and should adopt simple registration procedures and mechanisms.

Another approach to securing traditional water rights is to assign powers to the traditional management authorities. In Malawi, traditional water authorities participate in planning and implementing water development projects. The 1983 Burkina Faso Water Code and 1993 Niger Water Code also formalize local authorities' participation in these activities. The United States Environmental Protection Agency has involved Native American tribes in implementing water management policies, whilst the Namibian Act,

mentioned above, allows the Traditional Council (representing chiefs and traditional communities in general) to join the Water Advisory Council.

4.2. Integrating market-based regulations

Traditional water legislation has often favoured command and control mechanisms that require strong, centralized government oversight and enforcement. Although this type of mechanism has been effective in certain situations (such as in combating pollution or over-abstraction), it can also prove inefficient and overly bureaucratic in some settings. Accordingly, states are increasingly turning to the market as another means of regulating water resources and pollution. Market-based regulation strategies may include imposing taxes, creating financial incentives or establishing permit-trading schemes. Market-based mechanisms allow water users the flexibility and financial incentive to decide for themselves the least expensive means of complying with the regulatory requirements.

When governments give water users the freedom to pursue their own solutions through market-based regulations, corporations and other water users are given the incentive to innovate and thereby arrive at more economical and effective water use and pollution controls. Under market-based regulatory mechanisms, water users and polluters have more financial incentive to conserve resources or to use them more efficiently than if they were required to take a mandated action or install a specific technology to combat pollution (Stewart, 1992). Water conservation if employed in this fashion improves the company's or household's bottom line, saving money and improving profits.

It is important to recognize that even where there is greater reliance on market-based instruments, governments do not abdicate their authority entirely. Market-based instruments simply provide an efficient means for parties to meet their regulatory requirements; they do not remove them. Moreover, market-based instruments are not well-suited for all situations; command and control mechanisms may be more effective in certain situations and contexts. Indeed, many water resource management problems are best addressed by a combination of command and control limits and market-based flexibility. For example, the United States reduced lead in gasoline by first limiting the lead content of gasoline and then allowing refiners to trade the allowed lead content of their gasoline with lead content "credits". The federal Environmental Protection Agency gradually decreased

the allowable content by promulgating more stringent standards and reducing the number of credits circulating in the market.

4.3. Transforming government institutions

The structure of government institutions plays a central role in how state authority, responsibility and accountability are allocated across various agencies or ministries. Thus, enacting a comprehensive legal framework for integrated water management will often call for institutional and administrative reform (FAO, 1995c). A complete revamping of the water sector may well require staffing changes and changes in the responsibilities of ministries, agencies and councils, although in practice such changes are often neither politically nor financially feasible. In such situations, ensuring coordination among the relevant institutions and agencies must often suffice (see Box 3.2).

Box 3.2 - Fostering Cooperation under Albanian Water Law

Albania's Law on Water Resources (No. 8093, 21 March 1996) institutionalizes a high degree of cooperation between the National Water Council (NWC) and other public entities. Under the Law, the NWC is entitled to get information, data, reviews or technical and advisory support from other ministries, committees, agencies and public structures to enable it to prepare the National Water Strategy and National Water Resources Plan. The NWC is required to prepare, in cooperation with other concerned agencies, projects and programmes to prevent or remediate harmful impacts on water resources. These may address irrigation plans and crop cultivation practices, drainage, protection of river banks and reforestation, amongst others.

Albania's legislation has allowed for particularly close cooperation between NWC and the Ministry of Health and Environmental Protection. The Law provides that the NWC *must* collaborate with health and environmental protection institutions in areas posing a danger to human life and health. In accordance with the mandated procedure, the NWC first declares an area harmful to the public interest and then deals with the affected land and water. Furthermore, the NWC and the Minister of Health and Environmental Protection share responsibility for prescribing requirements for different kinds of discharges and for setting quality standards for water for human consumption.

Box 3.3 - Catchment Water Management Boards in Australia

The State of South Australia Water Resources Act (No. 27, 1997) establishes catchment water management boards. The Act provides that one member must be a woman; one must be an active member of a community within the board's catchment area; one or more must have expertise in the management, development or use of water or other natural resources; one must have expertise in the conservation of ecosystems; one must represent local government or administration within the board's area, and all others must have expertise in public or business administration, regional economic development or any other area that the Minister finds relevant.

Under the Act, the boards prepare and implement catchment water management plans, advise the Minister and the catchment area's constituent councils on water resource management and promote public awareness of the importance of proper management and sustainable use of the water resources of the catchment area. The boards have the power to stop, reduce the flow of, hold, divert or otherwise control water in a watercourse; deepen, widen or alter watercourses or lakes; construct embankments, wells, channels, roads, buildings or other works; excavate land to create a lake or for any other purpose; install pipes, machinery or other equipment; drill boreholes; inspect or survey land and fix posts, stakes or markers; dig to determine the nature of soil and remove samples; and acquire land by contract with a land owner on approval of the Minister.

Boards do not issue water allocation licences within their catchments, although water plans can empower them to grant water permits. Generally, allocation is carried out at ministerial level, with the Minister evaluating, issuing and amending licences in accordance with the relevant water allocation plan.

Many countries are moving away from centralized water administrations towards more local water management structures at the catchment, river basin or aquifer level. If local capacity is sufficient, many water resources management activities are more effective when administered at the local level. However, certain activities such as information collection and monitoring may be more efficiently managed by the central government, since local authorities may not always have the requisite knowledge or access

to information for informed decisions and may be subject to more political pressure than a central or national authority. Whatever the case, decisions affecting local water authorities must consider the local conditions (De Koning, 1987).

Within each nation, political, institutional and geographic factors will determine the appropriate level for decision-making. The technical capacity and expertise of regional government administrators and technicians will also affect decentralization decisions. For example, water authorities in New Zealand and Australia (known as catchment management authorities, see Box 3.3) have been restructured to exercise jurisdiction over particular watersheds. There the institutional scale is aligned with the hydrological scale.

4.4. Incorporating planning

Comprehensive water legislation should provide a framework for water resource planning, the principal aim of which is to predict the impact and needs of humans and the environment in relation to water resources. Water resource planning also aims to direct the development of water resources to meet human and environmental needs and to address potential harmful effects on the water resource, the surrounding ecosystem and dependent populations. Water planning is also used to mitigate any harmful effects that may be caused by water resources, for example through flooding, waterlogging or soil erosion. Insofar as possible, water management plans should aim toward the efficient and rational distribution of water to meet present and future water demands through the sustainable development of water resources. France introduced and regulated a complex water resources planning system in its 1992 Water Act (see Box 3.4).

Within Australia, the State of New South Wales' Water Management Act of 2000 mandates the formation of statutory water resources management plans for designated "water management areas". These plans, which are in effect for 10 years at a time, are to be formed by local committees and cover water resources allocation and sharing; environmental protection; drainage; and flood plain management. In the State of Victoria, amendments (2001) to the 1989 Water Act provide for "streamflow management plans" – prepared in respect of surface water resources under stress – to limit total water abstractions. South Australia's catchment-level "water allocation planning", introduced by the 1997 Water Resources Act, fixes volumes of water that can be taken from a catchment area for use.

Box 3.4 - Planning Provisions in French Legislation

France's elaborate water resources planning system is based on General Water Plans (*Schémas directeurs d'aménagement et de gestion des eaux*, or SDAGE), covering one or more basins, and on Detailed Water Plans (*Schémas d'aménagement et de gestion des eaux*, or SAGE), covering one or more sub-basins or specific aquifers. These instruments reserve good-quality groundwater so as to satisfy the drinking water needs of the population and apportion the available groundwater to the competing user groups by quotas.

One distinctive feature of the French water planning system is the direct participation of civil society in the formulation and adoption of the plans. If the government grants a water abstraction concession or permit that is at variance with the determinations of a SAGE or SDAGE, that concession or permit can be challenged in the courts and quashed. This ability to challenge conflicting government concessions is actively used in practice: in one instance, the state granted a permit for the extraction of groundwater for industrial use from an aquifer that the Seine-Normandie SDAGE had reserved for drinking water use. The permit was quashed by the court and withdrawn (FAO, 2003).

As described above, water policies should provide the flexibility to respond to developments in water resources assessment and technological and socio-economic change. In this regard, the new Netherlands Water Act (expected 2009) mandates that water management plans be reviewed every six years. Moreover, the preparation and periodic review of river basin management plans is a mandatory requirement for member states of the European Union (EU) under the EU Water Framework Directive of 2000.

4.5. Integrating environmental and ecosystem concerns

As described above, a comprehensive legal framework for water must adequately take into account the environment and ecosystems. Focusing on development to the exclusion of environmental concerns can lead to unsustainable water uses, water pollution and damaged ecosystems, as well as negatively affect the ecosystem services they provide and on which communities depend. Water laws should therefore require that water resource management administrators keep environmental considerations in view. For example, water laws may mandate

that before making any change in water allocation and management, government must carry out an environmental impact assessment (EIA). EIAs formally evaluate projects (especially but not only government-funded ones), assess whether they may cause any harm to the environment and finally, recommend ways to prevent or mitigate this damage. Most countries have legislation requiring these assessments where a particular activity may have a significant effect on the environment.

Many other countries mandate the use of a health impact assessment (HIA), which evaluates how a proposed policy, programme or project may affect the health of people. At a minimum, legislation could require that an EIA and a HIA be conducted for major projects such as the construction of a dam. The details of when an EIA and HIA are required and the procedures for conducting them should be clearly specified in the legislation.

Those countries that employ EIAs should consider broadening the assessment process to ensure that water resource concerns are specifically accounted for and adequately addressed. This can be achieved by tailoring the EIA to the relevant scale, i.e. the river basin or aquifer. Both the water resources and the ecosystem should be assessed for potential impacts. The EIA process should also consider the cultural and social values of water for the local communities, particularly for indigenous peoples (see FAO, 2003). EIAs may include measures to mitigate any harmful effects on local people and ecosystems, such as alternative sites for projects and compensation for any harm done.

The United States implemented its impact assessment process in 1969, when it passed the National Environmental Policy Act (NEPA). NEPA requires all federal agencies to prepare impact statements for major federal actions significantly affecting the environment. The assessment process established by NEPA has two prongs: an initial environmental assessment and, if warranted, a more comprehensive environmental impact statement (EIS). The EIS must detail the environmental impacts of the planned federal action and outline any available, less harmful alternatives.

4.6. Integrating health and development

Public health and development are inextricably linked to an adequate and safe water supply and to the level of water quality and sanitation. Public health issues must be integrated into every level of water management decisions, beginning at the strategy formulation stage and continuing through to project planning, design and implementation (FAO, 1995c). Water policies and

planning often neglect these issues, focusing only on water as it relates to agriculture, transport and energy. Health specialists tend to look at water quality only as it relates to drinking and recreation. Such divisions have created gaps in policy and legislation, as well as missed opportunities for more effective management of water resources.

Health and development concerns may be integrated in several ways. One strategy is to require close institutional cooperation between the water resources administration and the public health authority. In addition, health professionals should be included on any water strategy resources team during the policy review phase. In many cases, the ministry of environment, water resources or agriculture, without consultation, sets up a working group, develops draft legislation in isolation and then circulates the draft to other ministries (including the ministry of health) for comments. Similarly, health experts often develop health legislation on their own. Full participation of all ministries, relevant agencies and other stakeholders is required for legislation to reach all sectors. To the extent possible, water legislation should formally institute such cross-sectoral cooperation.

Impact assessments are one important tool for integrating health concerns into water policy. As described above, before development projects can be undertaken, environmental legislation often requires EIAs, HIAs or both. Health-specific impact assessments may either be part of an EIA or may be implemented separately. In either case the goal is to ensure that health issues related to the environment and water resources management are neither marginalized nor ignored.

Integration of health concerns is also essential with regard to water services provision, particularly where water supply is managed privately. Governments must protect consumers by mandating oversight of water service provision, balancing the profit motivations and expectations of the water businesses against the legitimate interests and expectations of consumers. In England, for example, where privatization of the water sector began in the late 1980s, water companies had the power to disconnect supply if consumers did not pay their water bills and also had the ability to limit supply as a means of enforcing payment. In response to mounting concern over the health implications of water disconnections, England's 1999 Water Industry Act removed the power of water companies to disconnect or reduce water supply for non-payment, and strengthened consumers' rights with respect to standards of service provision. Consumers' rights to water services provision can also be enforced through court decisions. For example, the High Court of South Africa (2001)

and the Appellate Court of Brazil's Paraná State (2002) upheld – on constitutional, human rights and statutory consumers' rights grounds – the demands of petitioners to have water service provided, although they were in default with respect to water charges.

4.7. Involving water users

Another legislative step toward improving water management is to establish a role for a water users' associations (WUA). WUAs – also known as irrigation associations, user associations or water user organizations – are ordinarily non-governmental organizations that farmers and other water users form to manage an irrigation system at the local or regional level. These users pool their resources, financial and otherwise, to operate and maintain the irrigation systems.

WUAs are created to benefit users. They can ensure that water is equitably distributed amongst all users (regardless of their location or the size of their property); the water supply is reliable; access to water is more responsive to users' needs; disputes are quickly resolved; canals and the system in general are well maintained; and there are fewer free riders and less water theft (IWMI, 2003).

Unfortunately, such benefits are not always realized. This may be due to poorly designed organizational structures, for example, where WUAs are managed from the top down instead of the bottom up. This means that local users who know the resource and community needs best may have little or no say in the organization, structure or development of the association. They may therefore come to feel little ownership of the WUA and avoid fee payments (IWMI, 2003). Furthermore, without adequate government guidance or the consultation of all stakeholders, influential users of the WUA may take over the decisions and the management of the irrigation system for their own benefit (Fayesse, 2004). Influential users may draw more water than they are entitled to, often because the agreements and organizational rules are ambiguous on ownership rights (Fayesse, 2004). Finally, if the benefits of being a member of a WUA are not understood to be linked with the costs, then users may become free riders rather than participate in the funding and management of the system (Freeman, 1989).

Many countries have formally recognized or informally set up WUAs. WUAs are generally created as separate legal entities that self-fund and have autonomy. If a country has already developed a system of WUAs, then

legislation may be required only to recognize local management systems or improve their operation to ensure equity in distribution and participation (for example, to readjust from top-down to bottom-up management). Or, if water resources are still managed by a centralized government and the government intends to devolve to a local, user-based management system, it will be necessary to enact laws that transfer management to the WUAs.

Unless there is a longstanding traditional system of community water management in place, WUAs require a strong legislative framework. Many countries include these provisions within one comprehensive water law. Other countries, especially those without a long history of such associations, create a separate legislative provision dealing with the creation and management of WUAs. Chile, Kazakhstan and South Africa, for example, include provisions for WUAs within their respective national water laws. Kyrgyzstan and Morocco, by comparison, have separate laws dealing with water user associations.

It is critical that political and administrative authorities legally recognize WUAs once they are created (Freeman, 1989). WUAs should operate as legal persons that may enter into contracts, hold bank accounts, employ staff and defend themselves in legal proceedings (Hodgson, 2007). Legislation should also ensure that WUAs maintain non-profit status, so that neither the organization nor its members are personally enriched from their water management activities. This helps prevent conflicts of interest. Legislation might also provide for an equitable membership requirement to ensure that the full range of stakeholders' views are heard. For example, associations may be mandated to include women, members from traditionally disadvantaged groups such as indigenous peoples and both large-scale and small-scale farmers.

Legislation should also address which agency will have regulatory oversight over WUAs. Although any state actor may play that role, the water resources management authority generally provides oversight and support (Hodgson, 2007). However, excessive oversight, especially by a central government, may diminish participants' role and management powers and intrude upon WUA decision-making practices (Hodgson, 2007). Governments must therefore balance WUAs' self-governance and self-determination rights against water user rights and good water resources management. They must decide on the appropriate supervisory relationship and how accountable the WUAs will be to both the state and water users. Germany, for example, limits the central government's role to auditing and to carrying out a residual, legal,

supervisory function. The central government may only challenge a WUA's decision if it is actually illegal.

On the other hand, the oversight bodies must stand behind WUAs when they exert control over free riders, and be willing to uphold the decisions of dispute resolution bodies. Without clear and unambiguous acknowledgement of the association's authority, free riders will exploit the system, and the WUA will have difficulty exerting control over them and over other members that do not cooperate (Freeman, 1989).

It is difficult for a WUA to be effective unless it has both responsibility for management *and* authority to exercise that responsibility. Thus, legislation should contain a clear guarantee that the government will transfer responsibility and authority to manage and control water to the WUA, and ensure that the WUA is fully prepared to take on that management. Capacity building efforts may be required.

V. CONCLUSION

Review of the national legal framework for water is laborious, but it is absolutely essential to ensure good governance and effective implementation of water policies. All aspects of the existing legal framework should be assessed to determine which provisions need to change. When national water policy and law are revised, it is particularly important to bridge the traditional divide between laws on water resources abstraction and water pollution on the one hand, and laws on drinking water and water services on the other. The review and revision of national water law and policy should take an integrated approach that involves the broadest spectrum of water uses and stakeholders in order to ensure that national water resources are comprehensively protected. Similarly, since the various water laws and regulations will often be under the jurisdiction of different authorities or agencies, any new administrative scheme must ensure effective coordination.

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INTERNATIONAL WATER LAW*

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Efforts to improve the policy and legal framework for water resources management must go beyond the national sphere. In part, this is because water bodies do not observe national borders. Globally, 263 river basins cross international boundaries, with one-third of these crossing the borders of more than two countries and 19 basins crossing five countries or more. The Danube, for example, flows adjacent to or through 18 countries (UNESCO, 2003). And because water is transient, actions taken in one country can affect the quantity and quality of water in others. The erection of a dam on the main stem or tributary of an international watercourse may affect water levels, fisheries, recreation and other uses both upstream and downstream of the dam. Similarly, pollution-causing activities on a watercourse in an upstream country will have effects on countries and users downstream.

With water bodies and catchment areas crossing national boundaries and with activities in one country having far-reaching impacts on water resources in others, coordinated and multinational actions are the best way to manage shared water resources. At the same time, ensuring access to sufficient quantities of usable water has become an imperative for the international community. International cooperation and collaboration offer the best chance to properly balance human and environmental needs whilst ensuring sustainable development, use and protection of water resources especially in the face of climate change.

Shared water plainly calls for both shared strategies and shared solutions. Nations must work in concert to find lasting regional solutions. This requires countries to exchange information and knowledge, as well as establish joint water management plans, surveillance, early warning systems, contingency plans and institutional arrangements with their neighbours.

This chapter introduces a range of international approaches to the complex challenges of water resources management. It describes binding and non-binding sources of international water law, including water-related treaties, conventions and agreements, general principles of international law and guidelines formulated by international organizations. Finally, the chapter discusses emerging principles in international water law.

I. BINDING INTERNATIONAL LAW

Like national law, international law expresses government priorities, sets up structures, embodies commitments and identifies acts and omissions that policy-makers wish to reduce or prohibit. International law is mutually agreed upon by two or more sovereign states. It consists of the rules that govern their relationships and is only binding on countries that ratify the agreements (Janis, 2003). Box 4.1 lists some of the principal international agreements elaborated to address water resource challenges.

As outlined briefly in the previous chapter, international law is generally accepted to emanate from four sources, which are recognized in Article 38 of the Statute of the International Court of Justice, the United Nations' principal judicial body. The four sources are: (1) international treaties, conventions and agreements; (2) international customary law; (3) general principles of international law; and (4) judicial decisions. Each of these is now discussed in more detail.

1.1. International water-related treaties, conventions and agreements

International agreements can be described by a variety of names, such as treaties, conventions, inter-state agreements, binding decisions of international and regional bodies and declarations (Caponera and Nanni, 2007; Shaw, 2008). Regardless of the denomination, international agreements establish rules and conditions that are expressly recognized by the nations that voluntarily enter into them. They become law through the mutual consent of these nations: upon signing, states legally bind themselves to observe agreements made between them (ICJ, 1945; Shaw, 2008). To ensure compliance, parties to a treaty may mandate that any breach of treaty obligations will have consequences. Some treaties impose fines or institute dispute settlement proceedings against states that violate them.

International conventions may be general or particular. General conventions (multilateral agreements) codify a given sector's rules of conduct (Caponera and Nanni, 2007) and can be sub-divided into universal (global) and regional agreements. Particular conventions, by comparison, regulate specific aspects of international law and may be either multilateral or bilateral. Once a state agrees to a convention and signs or registers it, the convention must usually be ratified by the state's legislature.

Box 4.1 - Major International Water Instruments		
Agreement	Year Enacted	Description
<i>International</i>		
United Nations Convention on the Law of Non-Navigable Uses of International Watercourses	1997	Spells out rights and obligations for all transboundary water; only offers general guidance; vague on groundwater and surface water systems; not yet legally binding.
Helsinki Rules on the Uses of International Watercourses	1966	Does same for transboundary rivers, lakes and underground aquifers; non-binding but widely respected.
<i>Regional</i>		
European Union (EU) Groundwater Directive	2006	Implements the provisions of the EU Water Framework Directive on the prevention and control of groundwater pollution; sets criteria to assess groundwater chemical status and to identify pollution trends; regulates input of pollutants into aquifers; and fights deterioration of all groundwater bodies.
European Union Water Framework Directive	2000	Covers all EU member states' surface and groundwater resources, both domestic and transboundary; states must adapt national legislation to the directive's requirements.
United Nations Economic Commission for Europe (UNECE) Protocol on Water and Health	1999	Requires member states to establish national/local targets for drinking water quality, discharge quality, water supply performance and wastewater treatment to reduce water-related disease outbreaks.
Protocol on Shared Watercourses in the Southern African Development Community Region	1995	Requires member states to enact legislation that provides for water abstraction licensing and wastewater disposal permitting.
UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes	1992	Requires member states to pass legislation regulating point source wastewater disposal and to adopt water quality objectives and criteria consistent with the parameters of the convention.

The type of treaty or convention determines both how it will become effective and the responsibilities that it will impose upon the signatories. Some treaties are “self-executing”, meaning that when a country ratifies a treaty it automatically puts the treaty and all of its obligations into action. These self-executing treaties can apply immediately and be judicially enforced (Kiss and Shelton, 2004).

Other treaties are not self-executing, which means that they require a signatory country to make changes to its domestic law to enable it to fulfil the treaty’s obligations. Such treaties might require states, for example, to pass new laws or amend existing ones in order to forbid, monitor or regulate certain activities, to establish licensing schemes or to create and appoint organs with specific tasks. In practice, treaties often have some elements that are self-executing and others that are not. That is, even treaties that are not self-executing may contain self-executing clauses that can be implemented immediately, whilst even treaties generally described as self-executing may contain provisions requiring additional domestic legislation or regulations. It is thus advisable to examine each treaty provision individually rather than describing the treaty as a whole.

Although domestic legislation and international treaties are governed by separate rules and systems, they affect and influence one another. A host of domestic legal obligations may arise from treaty enforcement, compliance and implementing mechanisms. This is especially true in nations with a legal system that automatically gives international agreements priority over domestic legislation. It is also true in cases where parties to a treaty agree between themselves that a treaty supersedes national law. In such instances, national legislation must be altered or set aside if it conflicts with the treaty’s provisions.

International water-related treaties, conventions and agreements are the prime source of legally binding rights and obligations between and amongst states. The next section examines various types of water-related agreements which are entered into to address different water management problems.

1.1.1. Framework agreements

By signing framework agreements, states commit themselves to specific principles and establish a process for future joint action on a specific issue. Framework agreements are aptly named, for they create the framework for

future actions that can take into account subsequent information and technical developments. According to agreed principles, subsidiary agreements or new institutional structures can be developed over time to address emerging issues (Berlin Recommendations, 1998). This flexibility explains why framework agreements are seen by many commentators and international donor organizations as the best way to achieve integrated management, equitable distribution and sustainable development.

Some framework agreements set out a series of substantive and procedural rules that govern the apportionment of water flows, the establishment of joint basin development plans, the launch of water development projects, the determination of equitable utilization or a combination of the above. These agreements generally provide for permanent, multi-state, institutional arrangements to administer the treaty's complex obligations.

A particularly important framework agreement is the European Convention on the Protection and Use of Transboundary Watercourses and International Lakes (the "Helsinki Convention"), which was initiated by the United Nations Economic Commission for Europe (UNECE). The convention was signed by 25 European countries and entered into force in October 1996. Under the convention, state parties must take specific measures to prevent, control and reduce pollution, to ensure ecologically sound and rational water management and to ensure the conservation and, where necessary, restoration of ecosystems (art. 2). It also commits signatory states to cooperate in developing harmonized policies and programmes in fields such as research, development and the exchange of information (art. 2(6) *et seq.*).

State parties are required to set emission limits for discharges of hazardous substances from point sources based on the best available technology. They must also apply biological treatment or equivalent processes to municipal wastewater, issue authorizations for wastewater discharges, monitor compliance, adopt water quality criteria and define water quality objectives (art. 3). Countries must develop and implement best environmental practices to reduce the emission of nutrients and hazardous substances from diffuse sources, in particular from agriculture (art. 3(1)). Moreover, states must employ environmental impact assessment procedures and the ecosystem approach to prevent any adverse impact on transboundary waters.

The Helsinki Convention requires countries to collect and monitor a wide range of data on water resources. For example, parties must monitor

emission sources to obtain information on the concentration of pollutants in effluents and carry out pollution-load assessments. Countries must compile information related to instream features such as water quantity and quality; aquatic and riparian flora and fauna; sediment; and extreme conditions in waters caused by accidents, floods, drought or ice cover.

Framework conventions often create a secretariat or working party to administer the treaty and carry out the day-to-day activities. Thus, for example, a Working Party on Water Problems (WPWP) and several task forces were established to implement the Helsinki Convention. One of the convention's most important task forces addresses monitoring and assessment of transboundary waters. Under Article 11 of the Convention, states must establish and implement coordinated programmes to monitor and assess transboundary water conditions. Such programmes aim to ensure that changes in transboundary water conditions caused by human activity do not adversely affect human health and safety, plant and animal health and life and soil and air quality.

In March 2000, the WPWP and contracting states developed and formally adopted *Guidelines on Monitoring and Assessment of Transboundary Groundwaters* and *Guidelines on Monitoring and Assessment of Transboundary Rivers* intended to harmonize monitoring and assessment systems. The guidelines call for coordinated implementation of water policies based on sound institutional arrangements that facilitate cooperation between nations. The guidelines also stress the importance of nations integrating a comprehensive understanding of the dynamics of the groundwater flow system and the geology and hydrology of the transboundary area into all national and transboundary water resources management decisions. The guidelines are strategic rather than technical, and specifically state that they are not legally binding.

Institutional agreements are a sub-category of framework agreements that establish an international forum or institution to oversee a shared water body. For example, an agreement made in 1994 by Angola, Botswana and Namibia provides for a Permanent Okavango River Basin Water Commission (OKACOM), whose advisory mandate spans the entire spectrum of water development and management functions in the basin. OKACOM's functions include assessment of water supply and demand; water planning; water pollution prevention; drought mitigation; and others. To further the agreement's objectives, OKACOM must formulate environmentally sustainable development and integrated management plans

for the entire Okavango River Basin. Similarly, in 1994, Kenya, Tanzania and Uganda agreed to establish the Lake Victoria Fisheries Organization (LVFO) to promote cooperation and coordination on all matters related to the conservation and management of the lake's fisheries resources. LVFO is an independent intergovernmental organization with its own operating budget that the member states fund in equal parts.

1.1.2. Subsidiary agreements

As noted, framework agreements often generate supplementary agreements or protocols that expand or elaborate on certain issues or concerns in the main agreement. One important example is the Protocol on Water and Health, which covers the prevention, control and reduction of water-related diseases in Europe. It builds and elaborates on the 1992 United Nations Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992 UN Convention). The protocol, which was brokered by the World Health Organization (WHO), marks the first major international initiative at the intersection of water and health. Noting a "serious burden of water-related diseases and problems in water management, water supply and sanitation" in the European Region, 35 countries signed the protocol at the Third Ministerial Conference on Environment and Health held in London in 1999. Twenty-one countries have ratified the protocol since then.

Both the 1992 UN Convention and the Protocol cover transboundary waters, which are defined in the protocol as surface water and groundwater that mark, cross or are located on the boundary between or amongst two or more member states of the UNECE or of the WHO Regional Committee for Europe (WHO/EURO). The protocol's basic objective is to "promote at all appropriate levels, nationally as well as in transboundary and international contexts, the protection of human health and well-being, both individual and collective, within the framework of sustainable development, through improving water management, including the protection of water ecosystems, and through preventing, controlling, and reducing water-related disease" (art. 1).

The protocol also specifies the measures that state parties must take in order to achieve these objectives, including ensuring protection of drinking water sources, providing a standard of adequate sanitation that sufficiently protects human health and the environment and establishing effective systems to

monitor situations likely to result in outbreaks or incidents of water-related disease (art. 4(2)). In addition, to meet the objectives of the protocol, parties must aim to provide universal access to drinking water and sanitation, as well as establish and publish local targets for the standards and levels of performance needed to protect against water-related disease. Furthermore, the protocol calls for the establishment of water management plans, surveillance programmes and early warning systems to respond to outbreaks and incidents of water-related disease (art. 13(b)). In effect, the Protocol provides a “floor”: states are free to implement more stringent measures over and above those outlined in the protocol but need not do so to be in compliance.

The Protocol mandates that before implementing any water management measures, states shall thoroughly assess the likely consequences and effects and take note of the possible benefits, disadvantages and costs for human health, water resources and sustainable development (art. 4(4)). Furthermore, parties have the duty to ensure that water management activities within their state jurisdiction are guided by principles such as precaution (see Section 3.1 of this chapter), polluter pays (see Section 3.2) and equitable access to water, and that the activities in question do not damage the environment in other states or jurisdictions (art. 5). To ensure successful implementation, the protocol emphasizes international cooperation and action, exchange of information and knowledge about water management problems and risks and the enhancement of public awareness (art. 11–13).

1.1.3. Water apportionment agreements

Water apportionment agreements allocate and assign transboundary river flows. State parties enter into such an agreement to formally allot each nation’s respective “share” of the transboundary river flow. Each country may then use and develop its share as it sees fit, according to domestic priorities and plans. Classic examples of this type of international water agreement are the 1944 Treaty apportioning the Rio Grande flows between Mexico and the United States, the 1959 Nile Waters Agreement apportioning the regulated flow of the Nile between Egypt and Sudan and the 1960 Indus Waters Treaty apportioning the flow of the Indus and many of its tributaries between India and Pakistan.

A 1994 agreement between China and Mongolia on the protection and use of their shared watercourses is a more recent example. Under this agreement,

the countries pledged to cooperatively survey, investigate and monitor the quality and flows of several transboundary waters and to develop and use the waters according to the principles of fairness and equity. The two countries also agreed to adopt measures to prevent and mitigate harm to waters and ecosystems from floods, ice runs and industrial accidents; to establish annual consumption quotas for the abstraction and use of transboundary waters; and to ensure that the established quotas are not exceeded.

1.1.4. Joint development agreements

Under joint development agreements, countries establish their respective rights and duties and agree to jointly develop a shared watercourse's water potential. Successful examples of this type of agreement include the 1964 Columbia River Treaty between Canada and the United States to develop the river's power potential, as well as the series of agreements entered into in the 1970s by Mali, Mauritania and Senegal – later joined by Guinea – to jointly develop the hydropower, navigation and irrigation potential of the Senegal River.

More recently, in 1996 India and Nepal agreed to develop the water and power potential of the Mahakali (Sharda) River. The joint development agreement signed by the two countries fixes Nepal's water and power entitlements, establishes India's obligations for water and power releases, determines how expenses will be shared and sets up an arbitration procedure. In addition, the parties pledged never to "use or obstruct or divert the waters of [the river] adversely affecting its natural flow and level" except by agreement (art. 7). The Treaty also sets forth minimum flow requirements and the details of benefit and cost sharing (art. 1–4).

1.1.5. Technical agreements

Technical agreements are limited agreements that focus on narrowly defined technical issues, such as pollution, transportation or a specific development plan. In the area of pollution prevention, Canada and the United States signed a Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes in 1997. The strategy encapsulates a variety of actions and programmes to prevent pollution and to eliminate toxic substances. It privileges incentive-based actions to phase out the use, generation or release of priority substances (Level I substances) in a cost-effective manner within the most expedient time. For other less critical substances (Level II

substances), the strategy encourages the parties to take pollution prevention measures or to conform to national laws and policies.

1.2. Enforcement of international legal instruments

Treaties, conventions and other international agreements are more than statements of intended future conduct: they create legally enforceable obligations (Janis, 2003). It is a basic rule of international law that states must observe and carry out in good faith the obligations set out in the treaties that they have agreed to be bound by (Kiss and Shelton, 2004). However, there is no existing international machinery to monitor compliance by states or to ensure that they fulfil their obligations. In most cases, it is not the threat of actual sanctions but, rather, the mutual benefits of adherence to conventions and international agreements (and the moral obligations to do so) that prevent states from breaching treaty provisions.

In certain circumstances, however, a special supervisory international organ may be created to monitor state activities. A treaty may set up a system whereby states are obliged to periodically report to a designated supervisory organ regarding implementation progress. For example, Article 16 of the African Convention on the Conservation of Nature and Natural Resources designated the Organization of African Unity as the organ to which states must report (Kiss and Shelton, 2004).

Although it is still unusual to come across supervisory organs that “override state jurisdiction” (Kiss and Shelton, 2004), it is increasingly more common (especially in the environmental and trade contexts) to see multilateral or bilateral agreements that create their own enforcement mechanisms which states, through ratification of the agreement, agree to abide by. Such mechanisms can include compulsory arbitration or recourse to a dispute settlement body established by the treaty. For example, Article 10 and Protocol II of the International Convention for the Prevention of Pollution from Ships provides for binding arbitration. Compulsory referral of disputes to the International Court of Justice (ICJ) is another way to enforce international obligations, although the ICJ only has jurisdiction to hear a case where the parties had previously agreed to refer to that court all disputes on a particular subject.

II. OTHER SOURCES OF INTERNATIONAL LAW

2.1. Customary law

International customary law is another source of international law, according to Article 38 of the Statute of the ICJ. As noted in Chapter 3, customary law derives from a group's repeated acts or practices, which the group recognizes as legally binding (Caponera and Nanni, 2007), and generally creates an expectation that a practice will be observed in the future (Janis, 2003). A customary practice will only become a general rule of international law if a large number of states consider it to be binding on them, and if the international community does not protest the practice's extension to international relations (Greig, 1976). It may be difficult to prove the existence of conformity in state conduct and to discern when the conduct is no longer simply "discretionary habitual practice" but authoritative and internationally valid (Bishop, 1962). On the other hand, customary practices do not bind those states that have consistently objected to them (Sands, 1994).

An abundance of customary law informs international water law. As a result of growing international acknowledgement of the need to cooperatively use and protect international rivers and water bodies, several attempts have been made to regulate international watercourses and to codify the existing customary principles on the topic (Lazerwitz, 1993). The last 35 years have seen a number of global, regional and bilateral initiatives in international water law. Some of these are described below.

2.1.1. Helsinki Rules

The work of the non-governmental International Law Association (ILA) codifying customary transboundary watercourse law was the most important of the early initiatives. In 1954, the ILA's first committee (the Committee on the Uses of the Waters of International Rivers) began a study of the legal aspects of water uses in international drainage basins. The study culminated in the so-called Helsinki Rules on the Uses of the Waters of International Rivers, adopted in 1966. For the first time, these rules incorporated the principle of equitable utilization, which holds that each state within an international drainage basin has the right to a reasonable and equitable share of the beneficial use of the basin waters.

The Helsinki Rules have subsequently been enlarged and amplified by additional sets of rules prepared by ensuing committees of the ILA over a period of 30 years and consolidated as a whole in the “Campione Consolidation”. Because the ILA is a private organization, neither the Helsinki Rules nor the supplemental rules have received formal recognition, nor do they legally bind states. Nonetheless, they have proven valuable to international law, constituting an authoritative restatement of customary international law on the non-navigational uses of international rivers, lakes and groundwater.

In 2000, the ILA revisited the Helsinki Rules, taking note of the Campione Consolidation, and in 2004 adopted a set of new rules known as the Berlin Rules on Water Resources Law. These rules attempt to incorporate the experience of the nearly four decades since the Helsinki Rules were adopted. In particular, the new rules take into account developments in international environmental law and international humanitarian law, as well as the framework treaty adopted by the United Nations General Assembly (UNGA): the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997), discussed in the next section.

2.1.2. UN Conventions

The International Law Commission (ILC) is the United Nations (UN) body responsible for the progressive development and codification of international law. In 1970, the UNGA directed the ILC to “take up the study of the law of the non-navigational uses of international watercourses with a view to its progressive development and codification” (UNGA Resolution, 1970). This task of trying to codify international customary law was not a simple one, given the different interests and practices of the member states. The ILC studied the topic for over 20 years, and in 1994 provisionally adopted “Draft Articles on the Law of the Non-Navigational Uses of International Watercourses”. It then recommended that the UNGA elaborate on these articles through a convention or an international conference of national representatives. The UNGA subsequently met as a Working Group of the Whole in the 6th Legal Committee. All UN member states and member states of the UN specialized agencies were welcome to participate and negotiate.

The UNGA adopted the UN Convention on 21 May 1997 with limited changes. A large majority of states (103) voted in favour, indicating broad agreement in the international community on the law of non-navigational uses of international watercourses. The 1997 UN Convention is at present the most significant restatement of customary international water law. The Convention applies to “uses of international watercourses and of their waters for purposes other than navigation and to measures of protection, preservation and management related to the uses of those watercourses and their waters” (art. 1). The convention is the only global international agreement covering the management and use of transboundary waters, and gives force to many general principles of water law (outlined below). It will come into force upon the ratification of 35 member states of the United Nations; as of 2009, 17 states had ratified the convention.

The UN Convention provides a framework that states can build upon and implement bilaterally and multilaterally for the use and development of transboundary watercourses. It has also proven useful in the negotiation and interpretation of other watercourse agreements that *are* binding upon states. In the event that the convention does not enter into force, its provisions would likely continue to serve as recommendations to states.

More recently, the efforts of the ILC have focused on codification of international law regarding shared groundwater resources. On 11 December 2008, the UNGA endorsed the second reading of a draft agreement on transboundary aquifers prepared with the assistance of the International Hydrological Programme at the United Nations Educational, Scientific and Cultural Organization (UNESCO). The resolution states that the proposed text is to be considered a basis for the future elaboration of a convention on transboundary groundwater. In the meantime, it recommends that states make bilateral and regional arrangements to manage transboundary aquifers, in accordance with the principles and provisions of the draft agreement annexed to the resolution (UNGA Resolution 63/124).

The five main principles set out in the draft text are the sovereignty of aquifer states, equitable and reasonable utilization, the obligation not to cause significant harm, the obligation to cooperate with neighbouring states and the regular exchange of data and information. The principles are largely the same as those established by the 1997 UN Convention. The draft also addresses water management, ecosystem protection, recharge and discharge zones and pollution control. The proposed agreement includes aquifer

management planning and monitoring of aquifer systems as essential management tools, along with the assessment of the potential impact of planned activities on shared groundwater resources. Emergency procedures are set out to ensure communication and joint action between parties in case of an “imminent threat of causing serious harm” to water bodies in any affected state.

2.2. General principles of international law

The third source of international law consists of general principles of law. General principles are seen as certain “basic legal notions of justice and equity” (Greig, 1976) and are expressed in most if not all nations’ domestic legislation. This source of law was inserted into Article 38 of the Statute of the ICJ to close any gaps in areas of international law due to the absence of an existing treaty or customary law (Shaw, 2008). Six general principles related to water resources management are outlined below, including (1) equitable and reasonable utilization; (2) no significant harm; (3) general obligation to cooperate and duty to exchange data; (4) protection and preservation of ecosystems and integrated management; (5) dispute settlement; and (6) exchange of information and prior notification on planned measures. Box 4.2 reviews an ICJ case which explicitly referred to several general principles of law.

2.2.1. Equitable and reasonable utilization

Equitable and reasonable utilization is one of the most basic principles of international water law. According to it, all states bordering an international watercourse – or states through whose territory segments of a river flow – have an equal right to use that watercourse. This principle is encapsulated in the UN Convention with the following language:

Watercourse states shall in their respective territories utilise an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be developed by watercourse States with a view to attaining optimal and sustainable utilisation thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse (art. 5).

Box 4.2 - General Principles of Law Cited by the ICJ

The Gabčíkovo-Nagymaros dispute between Hungary and Slovakia was the first water-related case to be heard by the ICJ for over five decades. The case concerned a 1977 Treaty in which Hungary and the former Czechoslovakia had agreed to build two dams on the Danube River, which would then be jointly operated. Alleging that the project would lead to significant environmental harm, Hungary suspended work on the project in 1989. In 1992, it attempted to terminate the 1977 Treaty after Czechoslovakia proceeded unilaterally to build on its own territory a single dam that required a diversion of 80 percent of the Danube's waters. Challenging Czechoslovakia's actions, Hungary relied on a number of international environmental law principles that had emerged since the finalization of the 1977 treaty.

The case gave the ICJ an opportunity to examine general principles of international environmental law relevant to transboundary watercourses. In its analysis, the ICJ stated that:

[T]he environment is not an abstraction but represents the living space, the quality of life and the very health of human beings, including generations unborn. The existence of the general obligation of States to ensure the activities within their jurisdiction and control, and to respect the environment of other States or of areas beyond national control is now part of the corpus of international law relating to the environment.

Moreover, in its holding, the ICJ specifically referred to the principle of equitable and reasonable utilization, stating: "by unilaterally assuming control of a shared resource the former Czechoslovakia deprived Hungary of its right to an equitable and reasonable share of the natural resources of the Danube". The ICJ also mentioned the obligation to cooperate, noting that in the management of international watercourses, cooperation between riparian states is crucial

This principle emerged from the Helsinki Rules and is generally rooted in the theory of limited territorial sovereignty, which posits that no state has an exclusive right to use an international river, lake or aquifer. Rather, each riparian state has the right only to reasonable use of the international water resource (Lipper, 1967). According to the International Law Association, the

principle of equitable utilization developed into an international customary law rule that forbids states to cause substantial injury to other states' territories (Lazerwitz, 1993).

The question of what constitutes "equitable and reasonable" utilization is generally decided through negotiation and according to the particular set of facts. To facilitate negotiation, the UN Convention sets out the relevant factors to be considered when making equitable utilization determinations, including geographical and hydrological factors; social and economic needs; the effects on populations that depend on the watercourse; conservation and economy of the use of water resources; existing and potential uses; and the availability of alternatives (art. 6). These factors do not have a fixed weight: the UN Convention states that "the weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors" (art. 6.3).

One weakness is that the weighting system allows each country to claim that its preferred factor is paramount in the evaluation of what is equitable and reasonable. As one commentator has noted, the effect of not stipulating a hierarchical order is that "the settlement of conflicting aims is likely to be informed more by power politics and other factors than the factors prescribed in [the convention]" (Elmusa, 1998). This commentator recommends giving priority to socio-economic and environmental needs, as this would create an opportunity for "a change in water allocations that reflect the changing circumstances" as well as an opportunity to encourage "more efficient uses" (Elmusa, 1998).

2.2.2. No significant harm

A second general principle of international water law concerns the obligation of watercourse states not to cause significant harm to the territory of other states. The rule is usually favoured by downstream states, as it affords their existing water uses a degree of protection against the actions of upstream states. This general principle of doing "no significant harm" is embodied in the UN Convention as follows:

Watercourse states shall, in utilising an international watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other watercourse states (art. 7).

The no significant harm principle provides that states must exercise due diligence to avoid significant harm when using an international watercourse. However, if significant harm results, the harm is not necessarily unlawful: it is unlawful only if it results from negligent or wilful conduct. Stated otherwise, the “no harm” obligation is one of intention, not of result. The second half of Article 7 sets out the consequences of lawful harm, which include payment to compensate for the harm suffered.

The principles of “equitable and reasonable use” and “no significant harm” are often viewed to be the “twin cornerstones” of the UN Convention (Lazerwitz, 1993). Article 7 seeks to avoid significant harm to the extent possible whilst achieving an equitable result in the specifics of each case. Thus, “equitable utilization” may accommodate a degree of significant harm. How much and what kind of harm would qualify as “equitable and reasonable” is debatable and may be negotiated between or among concerned states. Presumably, serious harm to human health and safety would constitute a breach of the principles of the convention.

2.2.3. General obligation to cooperate and duty to exchange data

The UN Convention includes the general principle of international cooperation, which requires watercourse states to cooperate in order to optimally use and adequately protect international watercourses. This collaboration is founded on sovereign equality, territorial integrity, mutual benefit and good faith. To facilitate cooperation, watercourse states may establish joint mechanisms or commissions (art. 8).

Similarly, the convention mandates that states must regularly exchange readily available data and information on the conditions of the watercourse, including data on water quality, hydrology, ecology, meteorology and related forecasts. States must also try to collect and process data to facilitate the use of the watercourse by other watercourse states (art. 9). States may request compensation for supplying other watercourse states with the information solicited (art. 9).

2.2.4. Protection and preservation of ecosystems, and integrated management

The UN Convention also incorporates the general environmental principle of preventive action, which obligates states to prevent damage to the

environment or otherwise reduce, limit or control activities that may cause harm. The convention requires watercourse states to “protect and preserve the ecosystems of international watercourses” and to harmonize their pollution policies to “prevent, reduce and control pollution of international watercourses” (Sands, 1994).

However, as with the “significant harm” principle, the UN Convention does not ban pollution. Rather, it establishes that states have a “due diligence” obligation to control, abate and prevent pollution that may cause significant harm. Even if significant harm does result from a polluting activity, if the polluting state argued convincingly that it had exercised due diligence, the behaviour and effects would likely be excused. The ILC had been inclined to regard such polluting activities as inequitable and unreasonable *per se*, whilst the UN Convention reflects a more nuanced balance between economic development and protection of human health and the environment.

2.2.5. Exchange of information and prior notification of planned measures

States have a specific duty to cooperate and exchange data when they plan measures that may affect or threaten any existing uses on a shared watercourse. This procedural principle was first recognized by the ILA in the Helsinki Rules (art. XXIX), and is elaborated upon in the UN Convention (art. 11). It includes a detailed procedure for prior notification. The obligation to notify other watercourse states in advance of any planned measures applies with respect to those measures that “may have a significant effect upon other watercourse states” (art. 12). Available technical information and data must accompany notifications.

Following notification, states may study and evaluate the planned measures for a six-month period, which may be extended for an additional six months if the planned measures are particularly troublesome (art. 13). During the six- or twelve-month period the notifying state may not implement or permit implementation of the planned measures without the notified state’s consent. If the notified state concludes that the planned measures are inconsistent with the principle of equitable and reasonable utilization or the principle of no significant harm, the UN Convention provides for a period of consultation and negotiation (art. 17). It urges states to try to find an “equitable resolution” to the situation through good faith negotiations that reasonably respect the

other state's rights and legitimate interests. These negotiations can delay the measures' implementation by an additional six months.

A special provision deals with urgent implementation of planned measures, where the measures are "of the utmost urgency in order to protect public health, public safety or other equally important interests" (art. 19). In such cases, the state planning the measures may proceed if it complies with the principles of equitable and reasonable utilization and no significant harm. However, the state must make a formal declaration of its plans in order to alert other watercourse states to the measures and their urgency and must provide relevant data and information. Other states may require consultation and negotiation after receiving the special notification (McCaffrey and Rosenstock, 1996). Some commentators have cited the inclusion of this obligation in the UN Convention as proof that the "international community as a whole emphatically rejects the notion that a state has unfettered discretion to do as it alone wishes with the portion of an international watercourse within its territory" (McCaffrey and Rosenstock, 1996).

2.2.6. Dispute settlement

Peaceful dispute settlement has been recognized by both the Helsinki Rules and the UN Convention as a general principle of international law. The Helsinki Rules state that "states are under an obligation to settle international disputes as to their legal rights or other interests by peaceful means" (art. XXVII.1), whilst the UN Convention goes further by providing a detailed dispute settlement procedure (art. 33). The UN Convention compels states to settle disputes through negotiation or conciliation or by agreeing to submit the dispute to arbitration or the ICJ. As noted earlier, the ICJ only has jurisdiction to hear a case if the parties have previously agreed to refer the dispute to it.

More controversially, the UN Convention provides that when the parties cannot settle their dispute through these means, or have not settled their dispute, the dispute can be submitted to a "Fact-finding Commission" (art. 33). The Commission must adopt a report by a majority vote and submit it to the parties, setting forth its findings, the reasons for its findings and such recommendations as it deems appropriate to resolve the dispute equitably. The parties then have to consider this report "in good faith". Although there is no real enforcement mechanism, certain states have voiced

concerns that this compulsory fact-finding mechanism is an infringement on their sovereignty.¹

2.3. Judicial decisions and scholarly opinion

The final source of international law is judicial decisions, which include judgments and advisory opinions of international courts, awards rendered by arbitral tribunals and decisions by national tribunals (Caponera and Nanni, 2007). The ICJ's judgments and various arbitral tribunal and national court decisions have contributed to and helped codify international water law, even though they are only binding on the parties to the case and lack the force of precedent.

Many general principles of international law have their roots in international and national case law. For example, case law brought about the recognition that states have limited rather than absolute territorial sovereignty over waters within their boundaries. This judicially created principle, established by the ICJ and developed by the decisions of other arbitral tribunals and national courts, underpins the essential principle of equitable utilization.

Under the theory of absolute sovereignty (also known as the Harmon Doctrine, after an opinion by Justice Harmon in a United States Supreme Court case from 1895), an upper riparian state may freely use and dispose of the water that flows through its territory. Later judicial decisions shifted toward a concept of limited territorial sovereignty, according to which upper riparian states may use the river waters so long as they avoid harming lower riparian states. This principle was expressed in the 1941 Trail Smelter Arbitration (TSA) case between the United States and Canada, where an arbitral tribunal found that Canada should have prevented a smelter on its territory from emitting poisonous fumes that caused harm in the United States.

Although the TSA case concerned transboundary pollution, it has been applied by analogy to water uses by upper riparian states that injure lower riparian nations.² In 1957, the Lake Lanoux case, which resolved a dispute between France and Spain about hydroelectric developments, further refined

¹ See for example the comments of China in the UNGA discussions prior to the vote on the UN Convention. UNGA Press Release GA/9248 (available at www.africanwater.org).

² The case is also used in support of the no significant harm rule (see Section 2.2.2 of this chapter).

the principle. It held that current international practice not only requires states to safeguard neighbours' riparian rights, but also to take account of "all interests, of whatsoever nature, which are liable to be affected by the works undertaken, even if they do not correspond to a right" (quoted in Lipper, 1967).

Finally, national courts have also helped develop international water law. For example, *Kansas v. Colorado* (United States) and *Württemberg and Prussia v. Baden* (Germany) aided the development of the principle of limited sovereignty and helped establish it as international law (Lipper, 1967). The former case supported the principle that two states have equal rights to water, whilst the latter resolved a dispute between two German states over the upper riparian state's water diversions, and ruled that the principle of equitable utilization mandated that "the interests of the States in question must be weighed in an equitable manner against one another". The German court held that one must consider not only the absolute injury caused to the neighbouring state, but also the relative weights of the advantage gained by one and the injury caused to the other (Wouters, 1997).

Scholarly writings include contributions by academics and scientific associations, as well as studies undertaken by lawyers on legal questions. These writings clarify the nature, history and practice of the rules of international law (Shaw, 2008). International legal scholarship may aid national parliaments in the preparation of legislation and may influence national and international court judgments. Apart from functioning as evidence of state practice, academic writings often highlight the defects in existing systems, influence states to adopt new practices and encourage debate about the values and aims of international law (Greig, 1976).

2.4. Non-binding instruments

The corpus of international law consists of non-binding instruments in addition to the treaties, conventions and other more formal agreements just reviewed. In the area of health and environment in relation to water, four non-binding instruments and mechanisms are of particular note and are reviewed in the next sections.

2.4.1. Millennium Development Goals (MDGs)

In 2000, 189 countries signed the Millennium Declaration, which outlined eight goals designed to improve the lives of the world's poorest people by 2015. These non-binding Millennium Development Goals (MDGs) are intended to provide a framework to aid development efforts, to provide countries with a common set of objectives to address poverty and to judge any progress that countries have made. The eight goals are:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

The MDGs reflect the international community's desire to see an end to the worst aspects of poverty and hunger. The last goal, calling for a "global partnership for development", acknowledges the role developed nations must play – and the actions they must take – to help developing nations reduce poverty and improve the quality of life for their people.

Accompanying these 8 goals are 18 targets to achieve the goals. Target 3 of Goal 7 seeks to halve the proportion of people without access to safe drinking water and sanitation, since the lack of one or both of these can exacerbate poverty and hunger. Water-borne diseases prevent adults from working and thus raising themselves out of poverty or feeding their families. In addition, as noted in Chapter 1, lack of access to safe drinking water often means that women and girls spend hours each day gathering water, which can prevent them from finishing school or pursuing livelihood activities.

2.4.2. Stockholm Framework

In 1999, following an expert meeting in Stockholm, WHO published a document entitled "Water Quality – Guidelines, Standards and Health: Assessment of Risk and Risk Management for Water-related Infectious Disease". Now known as the Stockholm Framework, the document sought

to address the perceived lack of consistency in health guidelines concerning water and risk management.

The purpose of the Stockholm Framework is to devise health-based guidelines and standards for hazards in water and sanitation. The document is intended to capture a “harmonised approach to the development of guidelines for water-related exposures to microbiological hazards” (Fewtrell and Bartram, 2001). Although it is mainly concerned with microbiological hazards, the Stockholm Framework may also be used to address chemical hazards. The framework calls for assessing health risks before setting health targets. It defines basic control approaches and outlines how to evaluate the impact of these approaches on public health status. The framework encourages a flexible approach, suggesting that countries adapt guidelines appropriate to their own social, cultural, economic and environmental circumstances. The framework now forms the backbone of various WHO guidelines, including the guidelines for drinking-water quality and for wastewater reuse.

2.4.2.1. WHO guidelines for drinking water quality

The WHO Guidelines for Drinking-Water Quality are based on the Stockholm Framework and provide a structure for countries to evaluate and improve their drinking water and sanitation standards. The guidelines outline certain control measures intended to help prevent microbial and chemical hazards from harming public health, and prescribe various management plans.

The guidelines define “safe water” and set benchmarks for how water suppliers should provide it. The guidelines also contain health-based targets that are based on a “tolerable risk” standard, which each country is to decide according to country conditions, current water quality and the willingness and ability of people to pay for their water services. The guidelines are discussed further in Chapter 7.

2.4.2.2. WHO guidelines for wastewater reuse

Wastewater reuse offers the potential to increase irrigation efficiency and improve nutrition and livelihoods but it poses health hazards, specifically from pathogens and chemicals. The concentrations of pathogens or chemicals vary according to “the number and type of industries that

discharge waste” and whether (or the degree to which) those industries treat the waste they are discharging (WHO, 2006). The WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater were revised in 2006.

Like the guidelines for drinking water quality, the guidelines on wastewater reuse have a health component and an implementation component (WHO, 2006). The health component defines the “level of health protection expressed as a health-based target for each hazard” and identifies “health protection measures that can achieve specified health-based targets” (WHO, 2006). The implementation component establishes the monitoring and system assessment procedures; defines supervisory and institutional responsibilities; calls for system documentation; and requires confirmation by independent surveillance (WHO, 2006). The goal is to ensure that effective systems and standards are in place to protect humans against exposure to intolerable risks of disease and other hazards related to the use of wastewater. The guidelines are discussed in more detail in Chapter 8.

III. EMERGING PRINCIPLES OF INTERNATIONAL WATER LAW

A number of emerging principles and concepts are shaping water resources management policy and practice and, more generally, the field of international environmental law. Although not yet customary rules or general principles of law, some of these principles affect state regulation of the use, development and management of transboundary waters. Each of these evolving areas of international water law is examined in the next sections.

3.1. Precaution

The World Charter for Nature (adopted by the UNGA in 1982) was the first international endorsement of the precautionary principle, which holds that the lack of a scientific consensus should not prevent a state from adopting preventive measures where an intended action or policy might cause severe or irreversible harm to persons or the environment. The precautionary principle was implemented in an international treaty as early as the Montreal Protocol on Substances That Deplete the Ozone Layer (1989) and appears in other international treaties and declarations. It is reflected in Principle 15 of the Rio Declaration on Environment and Development (Rio Declaration), signed at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992.

As stated in the Rio Declaration, precaution requires that “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Rio, 1992). In effect, the precautionary approach shifts the burden of proving innocuity on the one intending to take action rather than on those potentially harmed. The principle acknowledges the fallibility of human understanding and recognizes the scientific uncertainty inherent in environmental protection. In practice, states have differed on how much scientific uncertainty is acceptable.

3.2. Polluter pays

Under the polluter pays principle, any person or entity responsible for polluting the natural environment must bear the costs associated with remedying the harm. This principle has not been strongly endorsed by a broad cross-section of the international community (Sands, 1994) but it has received strong support in most OECD countries and in the European Community. This principle was also expressed in compromise language in the Rio Declaration as follows: “National authorities shall endeavour to promote the internationalisation of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the costs of pollution, with due regard to the public interests and without distorting international trade and investment” (Principle 16).

The polluter pays principle contemplates that the costs “associated with” pollution should be borne by those responsible for it. It is worth noting that these associated costs can include not only the costs of developing and implementing prevention, control and reduction measures, but also the cost of cleaning up impaired water resources and paying compensation for the loss, damage or harm that the pollution has caused. Although the polluter pays principle is well known and commonly embraced, applying it in full can be challenging because of the economic impact on polluting entities, and for this reason implementation tends to vary across states according to political will and regulatory frameworks.

3.3. Common but differentiated responsibility

The principle of common but differentiated responsibility holds that the special needs of developing countries must be taken into account in the

development, application and interpretation of international law. That is, due to their “differing capacities” (Vig and Axelrod, 1999), rich and poor nations should not be treated the same: rather, richer nations have an affirmative obligation to assist poorer nations and must bear the greater share of the costs of remedial action. This principle is expressed in the Rio Declaration (Principle 7) as follows:

States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth’s ecosystem. In view of the different contributions to global environmental degradation, states have common but differentiated responsibilities. The developed countries acknowledge the responsibility they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and the technologies and financial resources they command (Rio, 1992).

As applied to international waters, the principle might imply that developed countries should take on greater responsibilities with regard to the conservation, protection and restoration of the earth’s water resources or of water resources shared with developing countries.

3.4. Sustainable development

Sustainable development is generally defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). The term appears in the Rio Declaration, which states that to achieve sustainable development, environmental protection must be an integral component of development (Rio, 1992). The Rio Declaration enumerates various “strategic imperatives” of sustainable development, including, amongst others, meeting essential needs for jobs, food, energy, water and sanitation; ensuring a sustainable population level; and protecting and enhancing the resource base. The principle of sustainable development has been generally accepted in international discourse, partly due to growing concerns over environmental degradation, species endangerment, climate change and other pressing issues.

IV. CONCLUSION

One commentator has posited that water scarcity “need not necessarily result in heated conflict ... [but] can instead become the catalyst for increased co-operation” (Turton, 1999). The hope is that as countries begin to understand the pending dangers of water depletion, they will increasingly work together in pursuit of lasting solutions that benefit them all. The numerous agreements, conventions and protocols described in this chapter that cover shared waters and water management illustrate the experiences and willingness of states to cooperate in relation to water matters. In this respect, international law has been, and will continue to be, instrumental in defusing much of the potential for conflict over water.

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WATER RESOURCE QUANTITY: ALLOCATION AND MANAGEMENT *

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With an overview of the water cycle (Chapter 2) and national and international regulatory frameworks as backdrop (Chapters 3 and 4), this and succeeding chapters turn to the specific challenges of water management. This chapter examines the challenges of managing water quantity. Despite centuries of water resource development, water is still often not available for human uses in the right quantity at the right time and place. Water is therefore often “scarce” relative to the demands placed on it for human use and consumption. Similarly, as humans have altered the landscape and the hydrologic regime to meet their needs, this has meant that water is no longer available in the quantities and at the time and place required by species and ecosystems, which also provide valuable services to humankind. This is the essence of the challenge of sustainable water allocation and management.

This chapter begins by examining the water quantity function of watershed hydrology, groundwater and surface water. The chapter next turns to the rich complexity of the challenge humans face as they take on the task of managing water for human and ecosystem uses. This challenge can be broken down into several components: first, effective management is undercut by a lack of understanding, which is due to the technical complexity of the issues, a lack of good scientific information and the persistence of popular misconceptions about causes and effects in relation to water quantity. Second, there is a tension between the desire to manage water as a private good and the growing recognition that leaving the allocation and management of water to the market can have adverse effects on the social and environmental values of water. Accordingly, the chapter proposes a new conceptual classification of water-related goods and services in an effort to explain the public and private incentives operating on the various actors that provide or produce these goods and services. Third, the chapter describes institutional and governance challenges that function as yet one more barrier to effective water management. Finally, the chapter reviews legal and regulatory approaches – past and present – to managing water quantity.

I. THE PHYSICAL AND TECHNICAL CHALLENGE

1.1. Hydrology and water quantity

As described in Chapter 2, effective water resource management needs to take into account the hydrologic processes of watersheds, groundwater and surface water and how these processes inter-relate and interact. The

following section highlights the types of hydrologic functions and how these functions, and quantities of water, are altered by human activities.

1.1.1. Precipitation and watershed hydrology

Broadly speaking, upland areas in a watershed, whether in a natural or altered state, possess certain characteristics that determine how and at what rate the landscape and its associated vegetation transfer precipitation into groundwater or surface water. The specific characteristics of the watershed will also affect the quality of the waters, but this chapter focuses on the quantity effects.

Human activities that disturb or alter vegetation and soils can take many forms, and each type of activity will alter the hydrologic response from the watershed. The changes that occur vary depending on site conditions such as climate, topography, soils and vegetation. The main hydrologic responses include changes in:

- annual water yield, or in the total volume of water produced by the watershed on an annual basis;
- seasonal flows, particularly baseflow during the driest part of the year;
- groundwater recharge; and
- stormflow response or flood flows during major precipitation¹ events.

Each of these is described in more detail below.

Water yield. Ecosystems do not create water. They do, however, affect the amount and timing of water as it moves through the landscape (Brauman *et al.*, 2007). When human activities reduce vegetation (primarily through the removal of forests), the rate of evapotranspiration is usually also reduced, thus increasing the annual water yield from the watershed. This is the case in both temperate and tropical regions (Bosch and Hewlett, 1982; Bruijnzeel, 2004). In foggy or cloudy climates, however, vegetation can provide an intercepting surface that fosters precipitation of water droplets. One study of coastal redwood forests in California found that 34 percent of stored water had originated as fog, whereas fog contributed only half that amount in treeless sites (Brauman *et al.*, 2007).

¹ Precipitation itself is another hydrologic response, reflecting a feedback loop between watershed management and climate.

There exists a popular perception that forest areas produce more water than non-forest areas. This may be due to the fact that forests tend to grow where there is more precipitation. But precipitation causes forests, not the other way around. Moreover, an area maintained in natural forest may produce less water than if it were cleared, but the water that is consumed by the forest is consumed for a dual purpose: growing biomass, wood and trees, and providing habitat for species. Moreover, unless care is taken in removing the forest and subsequently managing the land, the water that is produced will likely be of lower quality and therefore of less value than that produced with the forest, due to higher rates of infiltration and natural filtering of runoff by forest vegetation. For the purposes of water quantity management, it is important to recognize that reforestation of previously deforested watersheds may well not increase water supplies downstream.

Seasonal flow and groundwater recharge. Human alterations of natural vegetation have a less clear-cut impact on seasonal flows, particularly on dry season baseflow.² Baseflow is of particular importance to water quantity management during the dry season, i.e. when at its lowest levels.

Although lower levels of evapotranspiration following vegetation removal can cause dry period baseflow to rise, this response may be reduced or even reversed if soils are so compacted by the subsequent land use that infiltration of precipitation is significantly curtailed (i.e. a reduction in the “sponge” effect ascribed to forests and other natural vegetation). Nevertheless, much experimental work has shown that the evapotranspiration effect overwhelms the infiltration effect. If infiltration rates are normally quite high, then severe compaction is necessary to reduce infiltration capacity to the threshold level where infiltration during normal precipitation events is affected.

Questions remain on whether experimental conditions sufficiently reflect typical real world conditions. Still, it is clear that the hydrological impact of land use changes depends not just on the impacts of the initial intervention but the impacts of the subsequent form of land use, as well as the type of management regime undertaken (Bruijnzeel, 2004). In other words, effective land management may well produce higher downstream baseflow after the conversion of natural vegetation to other uses, whilst poor management may

² Baseflow is the streamflow component derived from the discharge of groundwater, not that derived from overland flow during a rainfall event. As baseflow reflects water routed through the groundwater system, this discussion also applies to impacts of watershed management on groundwater recharge.

have the reverse effect. As one review article has concluded, “When groundwater storage is important, ecosystems that promote infiltration can be instrumental in improving supply Ecosystems such as upland forests and riparian buffers promote the transfer of surface water to groundwater by infiltration, which reduces flood peaks whilst increasing base flow, generally increasing the predictability of water availability” (Brauman *et al.*, 2007; Smakhtin, 2001). At the same time, studies in two Australian catchments found that shrub and grass ecosystems were more effective at ensuring summer time baseflows than tree-dominated ecosystems (Brauman *et al.*, 2007).

In sum, given the important variables of climate, soil, vegetation and land use patterns, it is difficult to make a general statement about the direction or magnitude of the effect on dry season baseflow of disturbing (or restoring) watersheds.

Flood flows. The relationship between vegetation, particularly forests, and flood flows may run counter to common perceptions. Science suggests that the effects of removal of vegetation on flood flows dissipates with distance downstream, and the threat from deforestation comes largely where the geomorphology is conducive to flash flooding, such as narrow canyons. In 2005, FAO and the International Center for Forestry Research (CIFOR) produced a policy brief reporting that the link between deforestation and flooding is uncertain (FAO and CIFOR, 2005).

Interestingly, one reason for the confusion over floods and forests relates to the institutional politics of governmental budget allocations in the twentieth century, for example as in the United States, where the Forest Service battled the Army Corps of Engineers to be the agency responsible for flood control (Calder and Aylward, 2006). As the century progressed, settlement of flood plain areas increased as did deforestation. As floods continued to ravage flood plain areas, deforestation and flooding were conflated, leading deforestation to become an immediate and convenient scapegoat, particularly in the media, for each new disaster (FAO and CIFOR, 2005).

For all of these reasons, it is difficult to be proscriptive regarding best practices for watershed management *vis-à-vis* water quantity. Upstream areas have many different productive and consumptive values for society and it is unlikely that land owners or governments will agree to manage them solely on the basis of downstream hydrological impacts. Furthermore, the common perceptions of the direction and magnitude of these impacts are not linked

to scientific understanding, making such manipulations even more problematic (Aylward, 2004). Some efforts to develop payment or incentive systems to encourage land owners to manage their lands are based in part on expected downstream water quantity benefits from improved watershed management. As outlined above, depending on the specific characteristics of the watershed, these assumptions may be unwarranted. A further concern, discussed below, is whether these schemes may suffer from the regulatory difficulty of ensuring that those that bear the costs can appropriate the expected water quantity benefits.

1.1.2. Groundwater

Groundwater consists of what goes in the ground (recharge) and what comes out (discharge), and it has both stock and flow components. In a natural steady state where groundwater stocks do not vary, the amount of recharge can be assumed to be equal to the rate of discharge. Groundwater quantity becomes a concern when humans or ecosystems rely on it and so alter its functioning. Reliance on or demand for groundwater comes at two junctures: extraction of groundwater (by humans) and natural discharge (for use by humans and ecosystems).

Groundwater has a renewable component – annual recharge and discharge – and an exhaustible component – fossil groundwater stocks. As noted above, human activities in upland areas that affect evapotranspiration can also lead to changes in groundwater recharge, thus ultimately affecting stocks and discharge of groundwater. If rates of extraction and net changes in evapotranspiration exceed natural recharge rates, then impacts will be felt on both stocks and discharge, which means that mining of the resource is occurring. If relatively minor rates of extraction are occurring then the impacts on discharge will likely be minor, as well.

A further complicating factor is that changes in recharge can be due not only to changes in land use and evapotranspiration, but also to changes in surface water bodies and conveyance. Large reservoirs and the diversion of large amounts of water into unlined canals can lead to significant increases in groundwater recharge. As new groundwater wells are drilled or as new diversions of surface water downstream from the point of discharge are developed, there will likely be increased competition for the existing flux of water through the system. If unchecked, this also will eventually lead to mining of the resource, despite the increased recharge.

Furthermore, as new human uses (of discharge or extraction) are developed, the amount of discharge available to surface waters for the maintenance of downstream freshwater ecosystems is diminished. Thus, management of groundwater, including its “upstream” linkages to watershed management (land use and evaporation) and its downstream linkage to surface water, will be critical to good water management. This can prove difficult, since groundwater development is “hidden” and therefore its impacts may not be immediately and fully appreciated.

1.1.3. Surface water

Surface water is appropriated for human use in a number of ways, largely through the diversion and removal of water from surface water bodies and the damming of rivers to generate stored water. In this manner, water is shifted from its natural time and place so that it will become available when and where humans need it for irrigation, municipal and industrial use, hydropower and transportation. In the case of flood control, dams are also used to hold back water during peak flow periods, and that water is then available for use in non-peak periods or during the dry season.

The consequences of this reorganization of the natural hydrologic regime can be extensive, with a cascading series of physical, chemical, biological and ecological impacts on the riverine and surrounding environment and on human populations nearby. The construction and siting of these facilities can also lead to massive dislocation and resettlement of populations, whether voluntary or involuntary. The competition for surface water and the resulting impacts and tradeoffs are better known than those surrounding watershed management and groundwater management, but even so, society as a whole has been slow to recognize and confront these challenges.

1.2. **Technical challenges in managing water quantity**

Given the nature of the water cycle, true integrated water resource management will require an understanding of watershed hydrology, surface water hydrology and groundwater hydrology, as well as knowledge of how these systems interact. The ideal tool for informed management would therefore be a suite of physical models permitting the analysis of these systems and their interactions and taking into account variables of human behaviour. Unfortunately, few examples of such comprehensive analysis exist. Furthermore, it is rare to see technical information integrated across

the physical systems. At present, the current state of knowledge permits only partial or step-wise exploration.

Quantitative efforts to assess the relationships between land use and land cover and impacts on evapotranspiration, surface runoff and groundwater recharge include paired watershed experimentation, statistical analysis of time series data and physical process models, to name a few. As suggested earlier, however, it is not unusual that in a given watershed there will be neither site-specific analysis nor a model available. There is a significant challenge therefore in making relatively precise predictions, as these will rely on a diagnostic tool that is data-intensive and requires an understanding of local conditions.

Modelling of surface water is perhaps the most straightforward endeavour in physical terms, given gravity and the conservation of mass (as water is neither created nor destroyed; it just flows downstream or evaporates). Modelling how human behaviour interacts with the surface water system is more difficult. Quantitative models should also account for storage and diversions. This would include predicting the operations of highly engineered systems with multiple dams in parallel or in series (which is amenable to sophisticated programming approaches), as well as analysing the behaviour of large numbers of irrigators, either on a few diversions or many. Although not insurmountable, this task may be difficult as it requires large amounts of historical data if the behavioural parameters and trends are to be well identified.

Modelling of both watershed hydrology and surface water is, however, incomplete without an accounting of subsurface interactions. Although numerical models exist that combine information on geological parameters with information on hydrology, they are necessarily imprecise given the assumptions involved and given the need to rely only on observation of inflows, outflows and levels of groundwater storage in order to assess model effectiveness. The seeming “black box” nature of the groundwater system (due to the ability only to observe what goes in and what comes out) can make it difficult for non-specialists to understand or have faith in such models. Moreover, such models can be expensive to develop and are unlikely to be available.

A further complication is that aquifers and watersheds do not necessarily sit on top of one other. As discussed in Chapter 2, an important question in

integrated water resource management is the unit of analysis and management. A watershed of a certain spatial size may sit astride one or more aquifers with different geologies, or it may share an aquifer with other watersheds. This may pose difficult problems for modellers, since water inputs to a basin may not equal outputs due to the difficulty of documenting inter-basin transfers that occur deep underground.

Another issue is that although water resources serve a wide range of human and ecosystem needs, the functions that are included in assessments and models tend to be those of the dominant user group. For example, in the United States, the Bureau of Reclamation's surface water distribution model is designed to accommodate irrigation water rights through storage nodes and points of diversion, but it does not have an explicit routine for accommodating instream water rights. In the absence of comprehensive science, data and models, it becomes that much more difficult to develop governance processes that lead to equitable and efficient water resource management.

1.3. Human and ecosystem uses of water quantity

In this book, freshwater is water of various forms that occurs in nature, including precipitation, surface water and groundwater. This may be called "ecosystem water", i.e. the water that is made available naturally by the water cycle and freshwater ecosystems. In its natural state, ecosystem water provides many goods and services to humans and the environment – the "ecosystem services" described in detail in Chapter 2.

Once ecosystem water has been regulated, diverted, pumped or stored by humans, it is transformed into a product that can be delivered to meet human needs. Examples include irrigation water and piped and treated water for municipal and industrial uses. Human ingenuity and effort add value to the raw ecosystem water; therefore, this type of water may be called "value-added water".

This value-added water can itself be transformed into a number of products and services ("water-related services") that humans use in household or productive activities. For example, hydropower facilities store water in order to generate electric power: power or energy is the water-related service. Flood control dams regulate flows to protect property and lives, providing another water-related service that safeguards downstream communities.

Human and ecosystem uses of water may therefore be classified according to whether they are ecosystem services, value-added water or water-related services. This classification reflects the degree of human investment required to generate useful services from precipitation, groundwater and surface water. Each use of water may also be categorized as having economic value in direct consumption by individuals, in production of goods and services of value to the household or in productive activities that generate goods and services for sale outside the home. Finally, each use may be classified by the extent to which it results in the full evapotranspiration of the water, i.e. whether it is a consumptive or non-consumptive use.

1.4. Water scarcity and tradeoffs amongst uses

Water scarcity is the fundamental physical problem in water quantity management. As demands are placed on ecosystem water, value-added water or water-related services, the combination of uses eventually leads to a shortfall in the availability of water or water-related services at the time of demand. Since water exists in the form of both stocks and flows, a deficit in water availability may be countered by drawing down stocks. Mining of groundwater reserves is one example. Storing water in reservoirs for later use during a dry period is another response to scarcity.

Scarcity leads to tradeoffs between different categories of use and between uses within categories. A tradeoff exists when there is not enough water to satisfy all demands and hence, a choice must be made as to how to allocate the available water across competing demands. A few examples from around the world are presented below.

United States of America

In the Western United States of America, historical reclamation of semi-arid and arid areas for the purposes of irrigated agriculture led to the dewatering of creeks, streams and rivers in the summer and the depletion of winter flows due to water storage in the headwaters. Where agriculture developed largely in valley bottoms in close proximity to the stream, water was effectively used and reused. It was diverted and applied to land, and the non-consumptive portion returned via the ground to the stream – and then the process repeated again at the next farmer's point of diversion downstream.

Such a pattern of abstraction often impaired the stream's capability to support fish and maintain ecosystem health. After the passage of many

environmental laws and regulations since 1970, this tradeoff between (value-added) irrigation water and ecosystem water has led to conflict and litigation over increasingly scarce water resources. In the last couple of decades, efforts at collaborative management of these resources have led to innovative approaches to achieving the voluntary reallocation of water from traditional out-of-stream uses to newly recognized instream uses that support ecological function. Many small non-profit groups, including “water trusts” and “river conservancies”, have been formed to help society revisit the tradeoffs made in the past (Neuman, 2004).

In the 1980s and 1990s, declining profitability of farming along with renewed population pressure on small towns and rural areas led to the development of formerly agricultural valleys into homes and resorts. With long-established farmers holding rights to most if not all of the surface water and with developers needing high-quality water for domestic purposes, many such developments have turned to groundwater for water supply. However, the connectivity between surface and groundwater means that these developments are merely intercepting the non-consumptive portion of applied water or natural recharge, which was previously diverted by farmers downstream.

State water codes penned a century ago often fail to account for this hydraulic connectivity and the ensuing tradeoff between water uses (Glennon, 2002). Efforts to update water legislation are vital to making these tradeoffs explicit. In Montana, partnerships between conservation and agricultural interests emerged to take these arguments to the state supreme court, ultimately leading to new legislation recognizing the importance of conjunctive management of surface water and groundwater (Trout Unlimited, 2007).

Costa Rica

Another example comes from Central America. Costa Rica is a middle-income country which has little in the way of fossil fuel reserves, but which is amply endowed with high levels of rainfall and short, steep watersheds along the Central American isthmus. In recent decades, the parastatal (quasi-governmental) agency responsible for energy, as well as private business interests, have turned to financially attractive small hydropower projects. These are often located in the numerous canyons that line the centre of the country. The facilities are typically run-of-river installations in that they do not require large dams or storage. Instead, they take water from the stream

or river and run it through pipes to a powerhouse located at a considerable elevation drop from the point of diversion.

Many of these sites are located in canyons that are also valued by local communities for their recreation and tourism value, since the same conditions that make for attractive small hydropower projects can also be of great ecological, scenic or recreational value for activities such as rafting. Local communities have raised concerns about being excluded from the selection and implementation of government power projects. New regulations requiring environmental impact assessments have provided one avenue for communities to participate in the design of such projects and the related decision-making.

India

In the Indian subcontinent, the seasonal nature of surface water supplies has led to the development of large storage systems to provide water for extensive irrigation schemes, although the more marginal classes of society are not necessarily the beneficiaries of the value-added water provided by such projects. This is because these projects often result in the involuntary resettlement of large numbers of people (WCD, 2000). In addition, for some groups, water that was available for domestic use is now impounded and sent down canals for irrigation.

South Africa

Under South Africa's previous government, large upland forests which formerly had only sparse native vegetation were planted with alien species. This increased evapotranspiration and reduced streamflow downstream. The new government revamped the national water law to guarantee water for ecosystems and to provide access to water for the bulk of the population, and sought to restore and protect flows in a number of ways. A new initiative called the Working for Water Programme was created in which unemployed workers were contracted to remove alien invasive species across the country. A streamflow reduction tax was also instituted, which would apply to plantation forests that have higher-than-natural evapotranspiration rates (see Chapter 9). Taking on a much larger responsibility for providing water to people and ecosystems, the government has recognized the tradeoff between land use and streamflow, and has implemented projects and policies to counteract past land use choices.

Changes in the pattern and extent of human demand for ecosystem water, value-added water and water-related services have caused greater water scarcity and prompted calls for explicit tradeoffs between different uses. Conflict can arise as water users gain or lose in the struggle over water quantity. The next section looks more closely at the nature and origins of these tradeoffs and the ensuing conflicts, before turning to potential legal and regulatory solutions.

II. THE SOCIAL AND ECONOMIC CHALLENGE

As stated earlier, the technical difficulties inherent in managing water quantity arise in the first instance from the physical complexity and interconnectedness of the water cycle and the resulting lack of adequate scientific information. But the key challenge in water management is increasingly recognized as more of a social than a physical problem. As explained in Chapter 3, the water crisis is increasingly understood as a crisis of governance rather than simply one of physical supply and demand. Water may be physically available, but the problem is how society organizes itself to make water available when and where it is needed.

In this section the root cause of this problem is analysed based on ideas from political economy: the concept of public goods and the problem of collective action. The discussion then reviews many possible solutions to this fundamental problem.

2.1. Fundamental cause of water management problems

The fundamental problem faced in water management is one of incentives. Incentives refer to more than just financial rewards and penalties: they are “the positive and negative changes in outcomes that individuals perceive as likely to result from particular actions taken within a set of rules in a particular physical and social context” (Ostrom, *et al.*, 1993). These incentives may be economic, social or moral. Regardless of the nature of the incentives faced by individuals (or groups), when taken as a whole the incentives available in a given situation affect the individuals’ evaluation of the costs and benefits of alternative courses of action, and correspondingly affect human decisions and behaviour.

In the case of water resources, the incentives that have governed human behaviour with respect to the management of water resources have often not

been consistent with balancing the different needs for these resources. This has resulted in economically inefficient, socially inequitable and environmentally unsustainable outcomes. The present chapter draws on the concepts of political economy to diagnose the fundamental cause of water management problems. The concepts of public goods and market failure are explained and then applied to ecosystem water, value-added water and water-related services.

2.1.1. Public good characteristics: exclusion and rivalry

The economic concepts of exclusion and rivalry define public goods (“good” here is shorthand for goods and services (Cornes and Sandler, 1986; Randall, 1983)). Exclusion refers to whether, once a good is provided, it is easy or difficult (i.e. costly) to exclude or limit consumption by other potential users or beneficiaries. Exclusion can be achieved through means of physical barriers and control (e.g. the application of technology) or through legal tools (e.g. a legal system of property rights). Goods can therefore be classed as excludable (high degree of exclusion) or non-excludable.

The second characteristic that distinguishes public from private goods is rivalry: the degree to which the use of a unit of a good by one individual reduces, or does not reduce, the potential for others to use that same unit. For instance, consumption of a piece of chocolate by one individual prevents it from being consumed by others. On the other hand, it is possible for many people to simultaneously access and consume a television show without affecting others watching the same show. Many natural resources and ecosystem services are conditionally rival in that at low levels of use they are non-rival but they become rival as congestion occurs (i.e. as more people use them).

The combination of these two attributes, exclusion and rivalry, proves to be a powerful method for understanding the incentives that different actors may have for the provision or production of different goods (Randall, 1983). Private goods are subject to exclusion, making them easy to confine or control. Those that want to consume them are excluded from consumption unless they pay the price the producers set. The consumption of these goods by consumers is also rival. Once the consumer has purchased the good, it is no longer available to other consumers. Because of this, if a demand exists, the producers have incentives to satisfy it, given that they can expect to cover production costs and even make a profit. A free market environment is generally considered to be the most efficient way for these goods to be

produced, allocated and consumed – provided that an institution (typically government) provides a stable framework underpinning the transactions.

By contrast, public goods do not lend themselves easily to exclusion, and they are non-rival. Once they are produced, everyone has access to them (although perhaps within certain geographic or political limits). Even those that do not contribute equally to the costs of production are able to consume them (and free ride). Because of free riding, producers have little incentive to produce, since their costs may not be covered. Hence, the provision of public goods requires collective action and is typically considered to be the province of government.

There are two other categories of goods beyond the purely private and the purely public. Common pool resources refer to those goods that are non-excludable and rival, such as a fishery or the open range. Like public goods, open-access common pool resources do not lend themselves easily to exclusion, but their consumption is separable. As long as total demand does not exceed the productive capacity of the resource, individual users can consume the goods without impeding consumption by others. When demand exceeds availability, congestion occurs and users operating on an exclusively voluntary basis have a strong incentive to continue appropriating the goods as fast as possible. Those that abstain from consumption simply yield benefits to those that continue consuming. And in the absence of a defined system of property or usage rights, all users are at liberty to consume the resource. Economists typically presume that this leads to an inefficient level of production since the resource is harvested unsustainably and the well-known “Tragedy of the Commons” ensues (see Box 5.1).

Box 5.1 - The Tragedy of the Commons

The “Tragedy of the Commons” seeks to explain what happens when access to a common pool resource is unfettered or unregulated. Each person with control over a portion of a common resource and no regulation or other incentive to keep his or her use in check will try to “maximize” his or her profit even if that profit is to the detriment of other users and the sustainability of the resource itself. This maximization causes other users to lose profits unless they, too, increase their use of the resource. Eventually, the common pool resource will be depleted, to the detriment of all.

Source: Hardin, 1968.

The last category consists of club (or toll) goods and services, which are non-rival in consumption but afford the possibility of exclusion. In this case, the ability to deny access to non-members may serve to limit the numbers of people seeking to share in the consumption. This may limit degradation of the good and allow some to enjoy its benefits. However, the benefits are ultimately non-rival (since demand increases relative to supply) and thus there remains the threat of congestion, for example if the number of members increases. In Figure 5.1, these two characteristics and the different classifications that emerge from their juxtaposition are presented.

Figure 5.1 - Public Goods: Exclusion and Rivalry

	Rivalry	
Exclusion	<i>Non-rival goods (low)</i>	<i>Rival goods (high)</i>
<i>Non-excludable goods (low)</i>	<u>Public goods</u> National defence Light houses Biodiversity	<u>Common pool resources</u> Rangeland resources Fisheries
<i>Excludable goods (high)</i>	<u>Club (or toll) goods</u> Private toll roads Golf clubs	<u>Private goods</u> Livestock Crops

In the analysis that follows, these concepts of rivalry and exclusion are applied to water resources to determine whether ecosystem water, value-added water and water-related services may best be regarded as public goods, private goods, common pool resources or club goods. Once their character is identified, the discussion turns to the institutional structure best suited to manage each type of good.

2.1.2. Exclusion and water

Speaking purely from the perspective of economics, bottled water is excludable, as an individual consumer can easily keep the water solely for his or her own consumption. Electricity generated by a hydropower plant is also excludable, since in order to enjoy the power a user must subscribe to the grid. Similarly, municipal and industrial water supply and irrigation deliveries are also excludable, since pipes, canals, laterals, ditches and headgates are all

designed to physically exclude non-participants in the system from access to water. Patrollers keep an eye on canals and laterals, as do land owners on their ditches, in order to prevent water theft. But there are degrees even here. Each of these goods can somehow be poached or stolen – with bottled water the easiest, followed by water piped underground, power on a grid and water in a ditch, in that order.

Waterways that have been re-engineered for transportation purposes, through channels, locks, canals and associated infrastructure, provide the opportunity to exclude potential consumers, particularly where lock systems are in place to raise and lower ships and boats from one waterway to the next. Flood control, on the other hand, is the one water-related service that is non-excludable. Once flood control structures are in place, they provide flood control benefits to everyone in downstream flood plain areas. The dam or levee owner has no way to physically exclude businesses and residences from locating in the area and enjoying the benefits of flood control.

The ecosystem water coursing through rivers, wetlands and lakes is a different story. In a state of nature, with no institutional protection or regulation, this surface water and the various services it provides are available to all comers. As surface water is always moving downhill, it is very difficult for a single user to prevent others from finding it. Likewise, it is difficult to exclude consumers from the recreational and fishing opportunities afforded through the creation of public reservoirs and other artificial surface water bodies.

With groundwater, its physical isolation provides an important barrier to human use. By controlling access to surface lands, one consumer may attempt to physically exclude others. However, aquifers are typically large compared to land holdings, making this a difficult proposition. Furthermore, current drilling technology allows wells to be drilled at angles to the surface. It is thus difficult for one consumer to exclude others whose land also covers the groundwater or is located nearby.

Precipitation falling on land is subject to physical appropriation and therefore exclusion. But this is possible only at a very small scale, for example where rainwater is harvested from impermeable surfaces such as roofs of buildings. Similarly, when a farmer alters land use and vegetation to grow crops, other consumers downstream are subject to any change in streamflow that occurs as a result of changes in evapotranspiration and soil

compaction on the farmer's property. Obviously, precipitation and consequent runoff and recharge from a property become part of surface and groundwater. There is only limited ability for a land manager to capture precipitation and change evapotranspiration rates (thereby excluding downstream uses), and thus this type of ecosystem water must generally be regarded as non-excludable.

It is important to note that as the good in question goes from ecosystem water to a value-added service (like irrigation) to a water-related service (such as energy), water tends to move from non-excludable to excludable. This is precisely because as human effort and resources are expended to store, divert and pump water, humans are able to exert more physical and institutional control over the water. Building dams makes water excludable because the stored water behind a dam is now under the physical control of the dam operator. Also, any increase in the height of water through impoundments gives the dam operator a certain amount of control over the potential energy of the water stored (for purposes of power production). Diverting water into a ditch or a pipe also increases options for excluding others from access to water. Thus, the degree of excludability varies directly with the investment in transforming water into useful products (like irrigation water, treated water or electricity) that can be transported to places of end use.

In economic terms, the ability to exclude others creates the possibility for the agent to appropriate the reward associated with the expenditure of effort and, as a result, provides an economic incentive to improve the accessibility of the resource to target populations. In other words, the ability to exclude strengthens the incentives for the agent to invest in improving the resource.

2.1.3. Rivalry and water

In the case of water resources, rivalry can be difficult to assess, depending as it does on a number of characteristics of the resource, the level of use and whether one views the resource from the perspective of an upstream or a downstream user. The first characteristic has to do with whether a number of users jointly consume the good (is the good "collective") or whether the good is available in discrete units ("separable"). Ecosystem water is typically a collective good – i.e. one that many different users may enjoy or use at once. For example, groundwater is a body of water from which many individuals may draw at any one time. Similarly, recreation on a river is collective, since quite a number of users may enjoy the resource

simultaneously without impairing the consumption of others. By contrast, bottled water is made available to consumers in discrete, separable units. At first glance, then, many water uses appear to be non-rival in nature.

Water is of course a multifunctional resource, which in practical terms means that the use of the quantity and quality of water by one user begins to impinge on the water's use by others. Goods subject to the problem of degradation or loss of function as use increases are referred to as "congestible" in the sense that as more users attempt to consume them the impacts of congestion are felt and there is a higher degree of rivalry. In the case of water resources this is the same as saying that the quantity or quality aspects of water become scarce relative to demand. In order to analyse the possibility of congestion it is first useful to define the quality and quantity of water that is "consumed" when water is used.

Almost all uses of water involve some physical manipulation of water whether through damming, diversion, abstraction or storage. In addition, many uses will alter the energy content, the chemical quality, the biological quality or other attributes of the water. For example, run-of-river hydropower diverts water from the stream and avails itself of water's potential energy. Transport is one use that has little to no impact on water quantity but simply uses the water's kinetic energy. However, as the level of use increases, the use of one function of water may conflict with (or subtract from the satisfaction of) another use.

Once a hydropower project sends water down a pipe towards a turbine, the potential energy of that water is fully consumed and is not available to other users. Nor is the water diverted from the river available to sustain ecosystem function. Therefore, a run-of-river hydropower project is potentially congestible in that the use of water for the hydropower purpose will be rival with other energy and ecosystem uses. This is of course true only in the reach where the water is diverted and run through a pipe. Once the water is returned to the stream, hydropower (in this case as a non-consumptive use) is non-rival with other uses downstream.

This suggests that rivalry for water resources can be examined from both an upstream (at the site of the use) and downstream perspective (Aylward *et al.*, 1998). Whether a given use is rival or not with other downstream uses – and more to the point whether it is congestible with regard to these uses – will depend on the extent to which the use of water is consumptive or non-

consumptive. Most uses result in some portion of the water being consumed physically, i.e. evaporated back into the atmosphere. The remaining non-consumptive portion of the water returns to the hydrologic system and is available, for example as groundwater or groundwater discharge, further down-gradient (assuming that there is no significant change in water quality).

Consumptive uses of water are therefore congestible goods from a downstream perspective in the sense that as they become scarce, adding additional uses upstream will subtract from the availability of water downstream. Irrigation, municipal and industrial uses will all typically be consumptive and therefore have attributes of congestible goods. Hydropower, recreation and transportation uses have a claim to be largely non-consumptive (absent storage) and therefore have non-rival attributes from the downstream perspective. This is because the diversion or use of water for power or transport does not reduce the potential use of this same water for downstream consumptive users.

Combining these characteristics into a single analysis is difficult but suggests that a number of the more passive ecosystem water uses will be non-rival in nature whereas many of the consumptive human uses of water (involving diversion, storage and pumping) are congestible. Once scarce relative to demand, the consumptive use of water by an upstream user is therefore likely to affect the water and services available to other users at the site or downstream, and exhibit rivalry. Meanwhile, the delivery of value-added and water-related services such as irrigation water and hydropower are generally non-rival when delivery is well planned and managed, i.e. where the majority of users use such systems without having an impact on other users. Of course, when poorly managed, these uses can become rival. Finally, the end use of value-added and water-related services such as bottled water, on-farm irrigation water, water from the tap and electricity in the home will of necessity be rival as the good is partially or fully consumed.

2.2. Economic nature of water

Water is often classified as a common pool resource, as are many other natural resources that in a state of nature are available to all but exhibit congestion at higher levels of demand and use (Ostrom and Ostrom, 1972; Dinar *et al.*, 1997). However, as illustrated above, the classification of water will depend on the type of water and on the use being discussed, as well as on the particular context. For example, irrigation water (a value-added good)

is identified as a common pool resource in a doctoral dissertation examining rivalry and exclusivity along distribution systems in Nepal (Lam, 1994), whereas a later World Bank study treats irrigation water largely as a club good (although with variations depending on differences in rivalry and exclusivity at the levels of the main canal, the distribution system and the turnout to the farm) (Dosi and Easter, 2003).

Figure 5.2 - Exclusion and Rivalry

Exclusion	Rivalry	
	Non-rival (low rivalry)	Rival (high rivalry)
Non-excludable (low)	<p><u>Public goods</u></p> <p>Ecosystem water</p> <ul style="list-style-type: none"> • Surface water <ul style="list-style-type: none"> ○ Boating ○ Cultural ○ Domestic ○ Recreation ○ Transport ○ Ecosystem support <p>Water-related services</p> <ul style="list-style-type: none"> • Flood control 	<p><u>Common pool resources</u></p> <p>Ecosystem water</p> <ul style="list-style-type: none"> • Precipitation* <ul style="list-style-type: none"> ○ Direct capture ○ Land use • Surface water* <ul style="list-style-type: none"> ○ Fishing ○ Diversion and storage of water for irrigation, M&I and hydropower • Groundwater extraction*
Excludable (high)	<p><u>Club goods</u></p> <p>Value-added water</p> <ul style="list-style-type: none"> • Irrigation water delivery • M&I water delivery <p>Water-related services</p> <ul style="list-style-type: none"> • Hydroelectric power • Transport 	<p><u>Private goods</u></p> <p>Value-added water</p> <ul style="list-style-type: none"> • Bottled water • On-farm irrigation water • M&I water at the tap <p>Water-related services</p> <ul style="list-style-type: none"> • Electric power at end use

*Goods that are congestible, so that at high levels of use relative to supply they would become rival and therefore common pool goods.

The classification of water that emerges from the above discussion is therefore necessarily imperfect and incomplete. Nonetheless, Figure 5.2

attempts to combine the analysis of rivalry and exclusion with the identification of the various uses (ecosystem water, value-added water and water-related services) as public, private, common pool or club. The emphasis here is on the analysis of these goods and services in a state of nature – that is, absent regulation. Later in the chapter the arrangements and regulations that have emerged to manage water resources for human uses are described.

Public goods. The use of naturally occurring surface water for recreation, transport and cultural purposes is largely non-rival. Many individuals may simultaneously enjoy the scenery at Niagara Falls, for example. Similarly, water's role in providing support to ecosystems and their ecological functions such as habitat for spawning and raising fish are generally available for enjoyment by all consumers. Value-added water for use in recreation and the water-related service of flood control are also non-rival. Consumption (enjoyment) of flood control by one downstream property owner does not affect the enjoyment of this service by his or her neighbours. Since it is also difficult to exclude users from the recreational uses of ecosystem water, these would also be prime examples of public goods. Of course, at specific times and at specific locations, these goods may be subject to congestion, in which case they would be rival and non-excludable and therefore classified as common pool resources.

Common pool resources. A number of ecosystem and value-added water uses are very susceptible to congestion, meaning that they will often be rival goods. For example, fishing as a use of surface waterways – whether natural or man-made – can easily become a lose-lose proposition as additional fishers enter the fishery. Domestic uses of springs or small creeks may also become rival as more people use them or as sanitation issues lead to water quality problems. Again, the problem with regulating the use of these goods comes from the lack of exclusion, or open access, combined with their rival nature. Absent any intervention, the resource will be degraded as existing and new users overuse it.

The act of diverting surface water or pumping groundwater for irrigation and for municipal and industrial (M&I) purposes has similar characteristics. At low levels of use, the diversion of units of water from a river may not affect other collective uses of the water such as recreation, fishing and ecosystem support. However, as levels of abstraction increase the river is dewatered, and the other uses provided by the river are affected. Furthermore, the abstractive uses are consumptive and therefore detract from the availability

of water for downstream users. In this sense, the use of water for irrigation and M&I purposes has the potential to be rival as usage increases. At the water source there is little or no possibility for one user to exclude another and hence the ecosystem water withdrawn for these value-added services must be regarded as a common pool resource.

Widespread access to electric power means that the potential to abstract groundwater through pumping is practically limitless in many cases. It can be argued that due to technological change associated with development of pumping capabilities and availability of electric power, the extraction of groundwater has gone from being excludable and non-rival (i.e. a club good) to non-excludable and rival (a common pool resource). Because mining of groundwater stocks (or surface water bodies) is feasible in technical and economic terms, groundwater use is therefore increasingly a rival use. Thus, the mining of aquifers, such as the Ogallala in the United States, and of surface water bodies such as the Amu Darya and the Syr Darya (which supplied the Aral Sea in Central Asia), are examples of rival uses, since present consumption reduced later consumption opportunities. As noted earlier, it is difficult to limit access to these stocks of water, so they are also non-excludable, making them common pool resources.

Similarly, the storage and release of water for irrigation, M&I or hydropower uses alters the hydrologic regulation of the river and therefore is rival with respect to uses that depend on the natural timing of surface water discharge. As with diversions, for dams there is generally no ability to exclude others.

These examples suggest that the extraction, storage, pumping and use of ecosystem water for these purposes are typically rival with respect to other human and ecosystem uses of water. This highlights the tradeoffs between augmenting the water services provided to humans and maintenance of ecosystem service benefits.

Club goods. The delivery of irrigation and M&I water and the provision of hydroelectric power through large distribution systems are non-rival. The incentive problem faced in these cases is that the cost of excluding others by building canals and delivery systems is significant relative to the benefits any one user might derive, and so collective action is therefore required in order to actually realize the benefits. Well-planned and managed irrigation or M&I delivery systems resolve this issue by sharing the costs of exclusion in an orderly fashion across large numbers of users. In this way it is possible to

exclude non-participants along the distribution system from access to the resource. Therefore, these distribution systems are non-rival and excludable and may be classified as club goods.

Private goods. Electric power – as the end product of hydropower generation and distribution – along with M&I water from the tap and on-farm irrigation water are separable and rival goods. Once the consumer receives the power or water, he or she can exclude other consumers from using it. In this respect, these end uses of value-added water and water-related services are similar to the case of bottled water, and all of these uses may be considered private goods. Should an end user so wish, he or she could take the power or water, repackage it and sell it to others in market transactions.

2.3. Institutional arrangements for water management

The preceding analysis shows that just a few of the end uses – but the dominant human end uses – of water are private goods. But this does not mean that the other uses are all public goods. A large number of the uses examined are not “pure” public goods (i.e. non-rival and non-excludable). Instead, they have only one or the other of the public good characteristics.

Economists have long held that an efficient allocation of resources is achieved by the market – but of course, this is only when the goods being allocated are private goods. The prevalence of public good characteristics associated with the many uses of water and its derivative services means that water itself ought not to be considered and managed as a private good, i.e. left entirely to the free market. This implies that society must therefore decide how to manage water, in all its forms and services, in a way that considers all the economic, social and environmental costs and benefits. The challenge is for society to settle upon an institutional structure that achieves effective allocations of water among the many competing demands.

There is not necessarily one answer to which institutional arrangement is appropriate for which type of good. Different goods and services associated with water are public or private to varying degrees, and these goods and services are also inter-dependent (Ostrom and Ostrom, 1972). In addition, a given use’s classification is not fixed, as a range of factors affect the excludability and rivalry of every good, as seen above. Similarly, since classifications will vary over time and space, an institutional arrangement that

succeeds in providing or producing the good in one site in an efficient manner may not do so in another.

Water services that are classed as club goods (such as power, irrigation and M&I) have often been regarded as natural monopolies since the capital investment in infrastructure required to build a distribution network on a sufficient scale may preclude competition. Moreover, if provided by the private sector, enough revenues must be generated to repay the investment. The allocation problem is therefore to provide an incentive for the financing and construction of such systems, part of which may involve guaranteeing to the private provider exclusive service areas (and therefore profits) in advance. For these reasons, large irrigation schemes have often been managed by centralized agencies, bypassing private provision entirely. For example, in the Western United States early efforts to promote the formation of private irrigation companies (under the Carey Act of 1894) failed, and the federal government stepped in and took on the task of building large irrigation schemes (through the Reclamation Act of 1902).

Once the system is in place, the issues change. In well-managed systems where potential users are easily excluded (unless they pay), there is the threat of monopoly power since the system operator exerts control. To counter this problem, many countries have chosen to require centralized provision of water through public utilities or parastatal organizations. Other countries have chosen a polycentric arrangement whereby private companies provide the network and services, but they do so under the regulatory authority of a public utility commission that sets rates and limits profits.

In poorly managed systems where exclusion is not enforceable, illicit taking of water may occur, reducing the consumption of water by legitimate members of the scheme. Alternatively, users may shirk their responsibility to pay. This can lead to problems of repayment of capital investment as well as inability to pay for maintenance costs. Thus, irrigation sector reform in many countries now promotes self-governance by water user groups.

In developed countries, the increasing demand for M&I water, a decline in agriculture, new interest in river restoration and the exhaustion of water supply sources are changing priorities and spurring innovation in institutional arrangements. In developing countries, unmet and growing needs for M&I water, along with poor cost recovery by municipal suppliers and irrigation schemes, have led donors and governments to rethink centralized provision

and experiment with other arrangements. Three of the major trends in institutional set-ups – decentralization, privatization and polycentric arrangements – are reviewed in the next section.

2.3.1. Decentralization

The local nature of many water problems has led to increased efforts to decentralize power and authority over water management from national governments to regional or local actors. Efforts to establish river basin organizations, watershed councils, catchment management agencies or groundwater management districts are evidence of this trend. As central government's role in allocating water has waned, centralized agencies have focused more on planning, monitoring and oversight.

The theory of decentralization originates from the so-called subsidiarity principle, which holds that government works most effectively when decisions are made at the lowest level that has the authority to decide (IUCN, 2003). The term “decentralization” is generic, and represents a variety of institutional arrangements. Traditionally, decentralization denoted a transfer of power or authority (fiscal or legislative) to sub-national governments (Ostrom *et al.*, 1993), but other power transfers are now recognized as forms of decentralization. Political decentralization, for example, occurs when the central government transfers decision-making power to locally (or regionally) elected representatives (WRI, 2003), whereas administrative decentralization means that the central government agencies or ministries transfer some of their functions to their regional or local branch offices. Other forms of decentralization consist of a sharing of power between the government and local users or between the government and local non-governmental organizations.

Decentralization, in any of these forms, can offer several advantages over centralized management. Because local authorities or groups have better contact with the resource and the actors that influence it, they may more efficiently apply policy and strategy goals to the water resource under their control. For example, local water users associations can internalize the costs and benefits of irrigation system management and reshape such systems to the real needs of users, rather than the needs perceived by central governments thousands of miles away.

However, decentralization can be wrought with the same problems as centralized management, such as lack of accountability (Ostrom *et al.*, 1993), which can arise in particular where power is devolved to unelected groups or institutions (as these groups may be loyal only to their members) (WRI, 2003). In order for decentralization to work best, the centralized government must transfer significant powers to an elected institution that represents all local interests and that is accountable, through elections or other democratic processes, to the local people. And of course, as with all forms of government, “[f]iscal and regulatory incentives must be in place to promote sustainable management of [the resource] over the long term” (WRI, 2003).

2.3.2. Privatization

Privatization is not an institutional arrangement in and of itself, reflecting rather a transition from a system with centralized, public provision of services to an arrangement in which the private sector plays a larger role. Whereas decentralization shifts power to local authorities with responsibility for local communities, privatization involves the private sector in the operation and management of water utilities (Dosi and Easter, 2003). In practice, privatization has often meant transferring water infrastructure to multinational corporations and leaving the ownership of water with the state.

Governments may choose to privatize municipal systems for many reasons, including reducing operating costs, avoiding future infrastructure expenses or achieving higher levels of efficiency (WRI, 2003; Dosi and Easter, 2003). In many countries, long periods of undercharging municipal customers and failing to increase charges to keep pace with inflation have left public service providers short of funds to maintain aging (and leaky) systems. Cost recovery, or lack of cost recovery, is the main problem. With no prospect of paying off new investments, municipalities are often unable to finance new infrastructure or services through loans or bonds. Experience suggests that an unspoken motive of governments privatizing water management is to pass on to the private sector the politically unattractive task of implementing or improving cost recovery.

If cost recovery is not the objective, then privatization is often undertaken because current management is perceived to be inefficient. However, the argument that private companies are more efficient is contested. Recent work from the United States suggests that there is little difference in

efficiency between public and private management of municipal systems (Wolff and Hallstein, 2005). In developing economies as well, years of encouraging private management have had mixed results in terms of increasing the efficiency of municipal service provision (UNDP and IFAD, 2006).

Since the private sector must have the potential to profit before it will engage in an activity, this means that it must either increase water prices or improve cost recovery to pay for expected improvements. To some extent, then, public anger over price hikes by recently privatized utilities in Manila, La Paz and other cities is misguided. In certain respects, public discontent represents more a failure of governance than a failure of privatization. If government is unable or unwilling to subsidize water users through the provision of public funding, then the private operator that is brought in to improve efficiency has no alternative but to raise prices. Clearly, however, passing this task on to multinationals without adequately preparing the public is a recipe for political turmoil.

Although there are potential benefits to private water management, there are also risks. Because private companies are beholden to their shareholders and are expected to make a profit, they may not necessarily be accountable to water users and also may not reinvest profits into improving infrastructure (Hilderling, 2004). For the same reasons, there are concerns that private water managers will not adequately provide services to the poor and under-served. Potential solutions are to increase government oversight or to require government to maintain infrastructure and provide service to all customers.

2.3.3. Polycentric arrangements

Polycentric arrangements are another option for governments considering various institutional structures for water management (Ostrom *et al.*, 1993). Polycentric arrangements give simultaneous and concurring powers and responsibility to national and local authorities: each geographical area has a government with the authority to make and enforce its own rules. In such a system, “[a]ll public authorities have official standing, and no individual group serves as the final, all-purpose authority that stands above the law” (Ostrom *et al.*, 1993).

The power and responsibilities that the different levels of government possess depend on the country and the type of power that is transferred, for

instance general powers of government versus specific powers given for one purpose such as maintaining an irrigation canal. Any disputes between the levels of government are settled in courts or other fora for alternative dispute resolution (Ostrom *et al.*, 1993).

Given the multi-faceted and inter-dependent nature of water resources, a flexible polycentric arrangement seems a logical outcome. This evolution reflects a shift from a dependence on centralized management of water to one that better captures the explicit call in the Dublin Principles to recognize water as an economic good. Seen in that light, devolving authority to relevant watershed bodies or user groups and increasing public participation in decision-making regarding water resources both grant water producers and consumers greater freedom to act in their economic interests. As already discussed, however, conceiving of water as an economic good (i.e. a scarce resource with value) should not be conflated with managing water using purely market arrangements. Water has too many public good aspects for this to succeed.

The remainder of this chapter considers the legal and regulatory approaches to allocating and managing water, considered in light of the challenges discussed above. This section does not address regulatory issues related to specific water-related services, such as drinking water, irrigation or ecosystem water, as these are explored in Chapters 7, 8 and 9.

III. ALLOCATING AND MANAGING WATER

The next sections examine legal and regulatory issues related to water quantity – specifically the ownership, use and management of water (see Box 5.2) – using national examples to illustrate the various options available to policy-makers. Where feasible, the discussion is organized around surface water, groundwater and watershed hydrology.

3.1. Ownership of water

Given the public good characteristics of ecosystem water, it is not surprising that the historical mode of regulating the ownership and use of water was for the government to retain an ownership interest and allow uses through licences, permits or use rights. Roman Law included the concept of common waters (common to all and thus no one could own them), public waters (belonging to public institutions) and private waters (associated with the

land). Islamic Law does not permit private ownership of water, nor does Chinese Law. The evolution of these traditions solidified the concept of state or public ownership of water in most countries around the world.

**Box 5.2 - Key Questions for Assessing Allocation
and Management in Water Laws**

Ownership of water. Does the state own water or can private entities own it? Does ownership vary for different types of water?

Use rights for water. If the state owns water or retains control over its allocation, how do public or private entities obtain state permission to use water? Which water uses require formal permission and which can simply be exercised?

Allocation of water rights. How is water shared in times of shortage? Are there rules for prioritizing the allocation of water to different uses?

Duration and transferability of use rights. What is the duration of the permission to use water? Does the permission depend on continued use of the water? Are use rights transferable between users?

Conditions on use rights, and fees. What conditions are placed on the use of the water? Are there state fees and charges associated with the use of the water?

Although it is often stated that water belongs to the public or to “all”, and this may be a powerful emotional concept, the counter-argument is that “what belongs to all belongs to no one.” In fact, the Roman concept of common waters that no one could own raises the question of how to manage the waters if there is no relevant authority. In practice, the concept of common water is generally understood to give government the role of managing water on behalf of the public, as well as the concomitant role of deciding who may use water and for what purpose.

The state’s legal role in protecting public goods such as water may be expressed in different ways and in different texts, such as a constitution or statute. In Indonesia, for example, the constitution places water and other natural resources under the state’s control, and the Ugandan Constitution states that the government must protect water resources on behalf of the people and manage the resources in a sustainable way. Under South Africa’s

National Water Act of 1998, the government holds water resources as a public trustee, whereas in Japan, rivers are public property and no one may have a private right over them. Although water is not mentioned in Kyrgyzstan's Constitution, the 2005 Water Code does specify that all water resources are the property of the Kyrgyz Republic.

In the United States, water is treated as a public resource. Private rights to the use of water may be established, but these are always incomplete and subject to the public's common need (Getches, 1997). The federal government and the states share jurisdiction over water resources, with the federal government generally regulating water quality and the states allocating quantity. In the State of Oregon, for example, the legislature declared in 1909 that all "waters of the state" belong to the public, with "waters of the state" defined to mean "any surface or ground waters located within or without this state and over which this state has sole or concurrent jurisdiction" (Oregon Revised Statutes (emphasis added)).

National constitutions and laws often treat different types of water (i.e. precipitation, surface water and groundwater) differently. Interestingly, Roman Law recognized rainfall and other waters associated with land (i.e. groundwater and minor waters) as private property. Civil law, which arose from the Napoleonic Code and applies in most of Europe and its former colonies, likewise distinguishes between water that falls and runs or pools on a property versus water that flows freely on the surface: only the former is amenable to private ownership. In Chile (where most water is national property), springs, non-navigable minor lakes, lagoons and swamps lying wholly within one's property are private. Indonesia also recognizes the rights of land owners over water flowing to and from their land.

In parts of the United States, water that is on the surface of land from rain, snow or floods is called "diffused surface waters" and is the property of the land owner. In the State of Texas, for example, this water is not subject to state control, and Texas courts have affirmed that until diffused water enters a natural waterway it is the property of the land owner (Kaiser, 2005).

Although modifying vegetation and land to appropriate rainwater will alter the timing and availability of water downstream, these are generally left unregulated by the state if water is the property of the land owner. However, the state does retain oversight to determine whether certain planned uses will affect other users. In the State of Oregon, for example, land owners planning

to irrigate with surface water or groundwater must obtain a permit to do so. Transfers in these use rights likewise engender state review to determine if other users will be adversely affected. At the same time, changes in land use or farming practices on rain-fed lands are not generally regulated, even though the change in land use will affect groundwater recharge and surface water runoff.

Unlike surface water, groundwater was considered private property under Roman Law. Civil law systems likewise recognize that water underneath a property belongs to the land owner, as do certain common law jurisdictions, including some states in the United States. Many states typically regulate groundwater separately from surface water, although some states have no groundwater rules at all (Getches, 1997). In 1904, the Supreme Court of the State of Texas adopted what has become known as the “rule of capture”, which simply states that land owners may extract as much water as they want from under their property. De facto ownership is thus exercised by extraction, allowing surface occupants to pump as much as they can. The lateral movement of groundwater from below one property to another is simply ignored (Kaiser, 2005).

In earlier times groundwater may have been regarded as a club good (i.e. non-rival and excludable), but modern pumping technology and the spread of electric power have greatly lowered the degree of exclusion that may be exercised whilst increasing the availability of groundwater for extraction. At the same time, the scale of use implies that one user’s use increasingly affects others’ uses; hence, in some locales, groundwater is increasingly a rival good. As a result, groundwater may now be regarded as a common pool resource with a need for common property management approaches. This is an example of how changing technology may alter the economic nature of a good, thereby calling for review of the legal framework if water is to be managed sustainably. Groundwater in this case needs to be actively managed, rather than allowing a “Tragedy of the Commons” to occur (see Box 5.1).

3.2. Use of water

A key characteristic of any system for regulating water quantity and its use is whether and which sorts of uses require some form of government permission. Under Roman Law the use of public waters (those that were

navigable) required authorization from the state. Similarly, the right to use waters from streams adjacent to riparian lands required state authorization.

In the Eastern United States, increasing growth and pressure on water resources led many states to adopt statutory permit systems by the middle of the last century (Getches, 1997). These permit systems were necessary in part for evolving non-riparian uses, such as for municipal supply. Typical uses exempt from permitting include domestic uses, farm ponds and, in some cases, irrigation. The State of Indiana, for example, does not require permits for riparian water uses limited to domestic, stock or agricultural water needs so long as withdrawals do not exceed 100 000 gallons per day.

In the Western United States, many states follow either the “prior appropriation” doctrine or a combination of the prior appropriation doctrine and the riparian rights doctrine. The prior appropriation doctrine originated from the customary practices of miners who resolved disputes over water based on who had first established a claim. All prior appropriation states have permit systems established by statute except for the State of Colorado, which adjudicates permits through special water courts in each water district. In most Western states, the permit system typically requires filing, public notice and review, followed by issuance of the permit. The permit is not a “perfected” right (i.e. the user cannot begin relying on it) until the user has demonstrated his or her intent to apply the water to a beneficial use. This is principally satisfied by constructing the infrastructure necessary to apply the water to the intended use, such as irrigation, mining or industry.

In Indonesia, uses are separated into beneficial and commercial ones. For the former, a licence is required for all beneficial uses that: (a) change a water source’s conditions, (b) are intended for small-scale farming outside of the irrigation systems or (c) serve people with high-volume water needs. All other normal household and local irrigation uses do not require a licence (Law No. 7, art. 8(2)). On the other hand, all commercial uses of water require a government licence.

In Uganda, land owners or occupiers who want to use water or construct any works on land must obtain a permit from the government, both for surface water and groundwater (Water Statute, art. 18). There are exemptions for water for domestic uses including drinking, cooking and washing. Also exempted are watering of livestock (not to exceed 30 animals), fire fighting and water for

subsistence agriculture, a subsistence fish pond or a subsistence garden (secs. 2 and 7(a)). For groundwater, a permit is required to drill any borehole.

Chile grants some water use rights without permits, and these are linked to land ownership. For example, rainwater that falls on a land owner's property may be used so long as it does not form a natural watercourse (Water Code, art. 10). As mentioned above, the water in minor lakes, lagoons and swamps may also be used by the land owner without a licence (art. 20). Finally, a land owner may dig a well on his or her property for domestic needs, even if that well harms the well of another, unless the harm is disproportionate to the benefits (art. 56).

In Krygyzstan, the water code requires permits for some water uses but not all. For example, domestic and personal uses, such as drinking and stock watering, do not require permits if the water is obtained from surface water sources and the construction of permanent waterworks is not required (art. 22(1)). Additionally, recreational uses, water for fire fighting and irrigation water supplied by a water users' association do not require a permit (art. 22(1)). Groundwater uses do not require a permit if extracted for domestic needs (art. 22(2)). Other uses, including dams, do require a permit.

Under South Africa's water law, domestic uses of water, including gardening, animal watering, fire fighting and recreation do not require a permit (sec. 4), whilst other uses do. Land owners and occupiers have the right to use the water on their land for domestic purposes. Other use rights, however, are not linked to land ownership. For example, an individual may obtain a licence to enter onto another's land to exercise certain use rights (Schedules 1(1) and 2). Groundwater is covered within the same scheme. An applicant may receive a licence to use groundwater that is under another person's property, but only if the land owner consents (sec. 24).

Japan's legislative framework classifies rivers as those that are particularly important for land conservation or the national economy (Class A – as designated by the Minister of Construction) and those that have an important public interest (Class B – as designated by the Governor of the Prefecture) (River Law, arts. 4(1), 5(1)). There are also rivers that are chosen by city, town or village leaders and regulated as Class B rivers (art. 100). Any person wanting to abstract water from a river must obtain permission from the Minister of Construction for a Class A river, or from the Governor of the Prefecture or the town or village leader for a Class B river (see arts. 9, 10, and 23).

From the preceding review of national laws covering water use, it can be seen that large users, including municipal, commercial and irrigation users, typically require permits. Household and stock water uses, on the other hand, tend to be free from permit requirements. This may derive from either a rights-based concept (as in South Africa) or from the perspective that rural household uses are not significant enough to regulate. Interestingly, as populations grow and development proceeds, water resources are becoming more fully exploited and the small uses that were previously considered “insignificant” and exempt from regulation may become more problematic for water managers.

3.3. Distribution and priority of use

The availability of water may be highly variable throughout the year, from one year to the next and from a wet cycle of years through a drought cycle. How legal and regulatory systems provide for allocation of such a variable resource is therefore of great importance both to managing water resources and to avoiding conflict.

The prior appropriation system used in most of the Western United States takes the “first in time, first in right” approach to allocating water for all current users. In these states, priority dates are established for each and every water right or permit. When water shortages occur, senior rights holders, i.e. those that appropriated water first, have the first priority for the available water, even if after their use no water remains for those who hold junior, inferior rights. In the State of Colorado, however, water users are prohibited in the summer from using water in excess of what is actually necessary for their irrigation or domestic uses (Colorado Revised Statutes). If the state government later takes water for other uses, depending on the circumstances it may need to pay compensation for “taking” the private water rights.

In Japan, permission to use river water is only granted if the Minister of Construction finds that new uses will not interfere with existing ones. There are exceptions, however, if a new project will provide a public benefit greater than that afforded by an older one. In such a case, the Minister may permit the new use after consulting with the heads of other interested administrative agencies (arts. 35(1) and 40). In Japan, then, existing use priorities are acknowledged but not to the exclusion of valuable new uses. This is not dissimilar to the case of Chile, described above, where a well dug on a land owner’s property to get water for domestic needs is allowed even if it harms

another's well. Here the potential benefits from new uses are not ignored, but they are balanced against the costs they impose on others.

Drought provides the extreme case of shortage and the inevitability of cutbacks for at least some water users. In the case of unusual drought in Japan, the authorities may intervene to ensure that permittees cooperate with one another to agree on water use. In drought periods, the oldest use does not necessarily receive priority: rather, there is an expectation that users will agree on the best use of water. If they cannot agree, the river administrator may require mediation or arbitration, particularly if an unmediated situation could harm the public interest (art. 53). With the river administrator's permission, a water user may permit other water users in greater difficulty from the drought to use his or her water allocation for the duration of the drought. The Industrial Water Law also gives the government certain authority in times of water need. For example, the governor may restrict groundwater abstraction when groundwater may be depleted (art. 14). The Japanese system provides a process for allocating water to higher-value uses, but this is left to the water users to decide.

Indiana, an Eastern riparian state of the United States, limits water withdrawals in the case of groundwater or surface water emergencies, which are defined in the state's water code. When the Department of Natural Resources (DNR) determines that water withdrawals have significantly lowered the normal levels of a lake or aquifer, and the lowering was caused by a "significant water withdrawal facility" (i.e. a facility that withdraws more than 100 000 gallons of water per day), then the DNR may restrict the amount of water that the facility withdraws. In this way, smaller facilities are preferred. Users that withdraw smaller amounts of water are typically land owners who use groundwater or riparian water for domestic supplies, whereas the significant water withdrawal facilities are large irrigators or industry. According to the state water code, "The use of water for domestic purposes has priority and is superior to all other uses" (Indiana Code).

Another approach to prioritization comes from customary law irrigation systems, known as *subak*, in Bali, Indonesia. There, *subak* members have a right to receive water from the water source in a fixed share that is determined by their contribution to the construction of the irrigation system: this has no relationship to the size of their plot of land. It is worth noting that this system pertains more to the water-related service of irrigation water delivery than permission to use the source itself, since without the irrigation

system the water could not be diverted. This system is therefore analogous to methods for balancing investment and return on large irrigation projects. The larger the investment a user makes in the system, the larger the right to the product of the investment, i.e. irrigation water.

The legislation in Chile defines several categories of water use rights. Consumptive rights entitle the owner to use the amount of water that is necessary for a given activity, whereas non-consumptive use rights require the owner to return the unused portion of water. Contingent use rights provide rights to any water surplus left over after the permanent right holders have satisfied their needs. Rights are further divided into continuous and discontinuous rights: the former can be exercised without interruption, whilst the latter can only be enjoyed at certain times. These categories are designed to assist in the management of variability in water supply.

The Krygyz Water Code provides a detailed ordering of water use priorities, namely: (1) drinking water; (2) irrigation and stock watering; (3) hydropower generation; (4) industrial activities (e.g. mining); (5) fishing and fish farming; (6) sport and recreation; and (7) any other purposes (art. 24). The legislation also permits the government to limit or restrict water use in times of drought or water shortages (art. 74).

In its 1998 Water Act, South Africa established a clear priority for basic human needs and ecosystem uses of water. These two uses are superior to all others, including those recognized under the prior 1956 Water Act. Apart from these two uses and international obligations, no set priorities are defined for normal, licensed uses of water.

Thus, a number of approaches exist to prioritize which potential users may access water and for which specific uses. An explicit, centralized approach may prioritize use rights based on perceptions of their societal necessity or worth (e.g. Krygyzstan and South Africa). In a locational approach, such as in the case of traditional riparian rights, those with land adjacent to the river have access, or higher priority access, than those farther away. Moreover, in times of shortage, the closer to the source the users are, the more chances they have to obtain water. Some jurisdictions may combine a centralized approach and a locational approach, designating priorities for non-riparian uses. A third possibility is to establish priority based on established versus new uses. One variant of this last approach is the prior appropriation doctrine, which fully differentiates among all permitted uses based on their

date of establishment. It is important to note that the United States is the only country that uses prior appropriation.

It can be difficult for a riparian system to accommodate the many competing uses, many of which will be non-riparian. The weakness of prior appropriation systems is that there is no clear relationship between the longevity of use and social, economic or environmental value. Centralized allocation systems may therefore seem the best option, except that laws and regulations most often only define categories of use in general terms, with the actual priority of allocation left to the executive branch to decide. Accordingly, there exists a very real possibility of rent-seeking behaviour, where government officials with the power to determine allocations are susceptible to influence (and bribes) from water users. This may result in a less than optimal allocation of water from a social, economic or environmental perspective. A second difficulty is that such a system is based on the assumption that government – even in the absence of rent-seeking behaviour – can pick the “best” use of available water.

An alternative is to let market forces determine the “best” result through water trading. In Australia, for example, the National Water Initiative (NWI), passed by the national and state governments in 2004, encouraged water trading to promote a more profitable use of water. Some United States states that follow the prior appropriation doctrine also have trading schemes. In these systems, some users have secure allocations (senior users) and some users have interruptible supply depending on hydrological conditions (junior users). If a junior user or a prospective user has a more valuable use, then he or she may apply to use water assigned to a senior user. The senior user then reduces or retires his or her use of water, but obtains compensation for the water transferred. This allows both parties to improve their situation through the trade of the permission to use water, resulting in a more financially efficient allocation of water.

The drawback of such a purely market approach is that disadvantaged social groups may not have participated, and the interests of the environment may not have been taken into account. Water may have moved to the activities with the highest market return but these may not be the activities with the highest value to society as a whole. For this reason, further regulation or restrictions on the market may be necessary. One solution is to prioritize categories of uses and then allow trade within, but not between, categories or across certain categories. For example, domestic supplies could have first

priority; minimum ecosystem needs might be the second-tier category; and industrial, commercial, agricultural and additional ecosystem needs would come last.

Another possible solution is not to make explicit *a priori* prioritizations but rather to follow the Japanese approach where the government compels the users to make the hard choices of how to prioritize the use of available water in times of shortage. This approach may succeed where central power is strong and there is a tradition of communal management of resources. Where this is not the case, the approach taken in the State of Indiana may have merit, where, upon request from water users, the water commission will mediate disputes.

3.4. Details of use rights

The details of use rights have important economic effects. These will include the duration of the permit, the ability to transfer a permit from one user to another and the requirement to forfeit the permit in certain circumstances.

The expected duration of the permit has an important effect on incentives for investment. All other things being equal, a short duration will discourage investment, whilst a long duration will encourage it. Also relevant will be the degree of certainty that the permit and its validity will not be abrogated by the issuing agency.

Transferability of permits allows trade in water when the original permitted use becomes economically unproductive. One system of transferability is called a cap and trade system, whereby the government establishes a withdrawal limit for a group of users but then allocates allowances for each user. The individual users may then trade their allowances amongst themselves, so long as the overall withdrawals remain within the authorized limit. Such a system may be more efficient than one in which unused permits are simply forfeited through non-use, especially where new rights were simply doled out without regard to their productive role in society. (See Chapter 9.)

A third condition of the use permit that will have economic consequences is the threat of forfeiture for unused permits and the ability to transfer a permit to another user. If there is no compulsion to use the water, then there is not as much urgency to do so. This means that over time the number of

outstanding permits will increase, since water is not being used and new permits are being issued. Potentially, this may cause confusion and problems once the water source becomes legally over-allocated. For example, if market conditions change for the better, and agricultural permits are put back into use, then this may lead to conflict over water or harm to low priority uses.

Many combinations of these three components of a water quantity regulation regime (duration, transferability, forfeiture) are possible. From an economic standpoint, permits that are valid in perpetuity, transferable and subject to forfeiture for non-use appear to ensure the most productive use of water in market terms. However, as discussed further in Chapter 9, this relies on the willingness of users whose use is on the downturn to trade their water to higher value uses. Also, it relies on new uses having the market power and financial resources to acquire water rights. It is not clear that environmental and social uses, such as ecosystem services or drinking water, will be in such a position. Without some sort of centralized oversight to ensure that water moves both to where it is needed and where it is socially productive, issuing water permits in perpetuity may be problematic, locking in private gain at the expense of the public benefit. Conversely, granting only short-duration permits is unlikely to promote investment in the efficient use of water.

A variety of approaches have been tried in countries granting use permits. In Kyrgyzstan, applicants for water permits generally receive them for 15 years, with two exceptions: where the applicant requests a shorter duration or where the permit is for gravel or mineral extractions, for which the duration is 5 years. Long-term investment works, such as dams, may receive a special use permit that is valid for up to 50 years. Permits for irrigation in Kyrgyzstan are transferable, although the new permit holder must register the transfer within two months or the permit becomes invalid. On the other hand, the legislation permits the government to limit or restrict water use in times of drought or water shortage.

In South Africa, all water licences are subject to a term of duration, for which the absolute limit is 40 years. All licences are subject to review at regular intervals, although the intervals cannot be more than 5 years. During the period of validity the amount of water specified on the licence may be reduced if the water use is not implemented fully (or at all). Only licences for irrigation may be transferred, and only temporarily. Licences may also be partially or fully surrendered in certain circumstances.

In Uganda, the transferability of the permits is only allowed when the land to which the permit applies is sold or transferred. The permits are thus attached to the land – a concept known as appurtenance. Anyone who buys or takes over property as to which there is a permit granted may continue to use water in accordance with the permit conditions for three months, after which he or she must apply for a new permit. The conditions attached to the new permit may not be more stringent than the previous ones.

Under the riparian doctrine in the Eastern United States, water rights are also regarded as transferred with the land to which they are appurtenant (Getches, 1997). A failure to use water does not usually result in forfeiture of rights. By contrast, under the prior appropriation doctrine in the Western United States, a failure to use water for a “beneficial use” can lead to forfeiture. The arid nature of the West prescribed the necessity of a system structured on the principle of “use it or lose it”.

Depending on the particular permits and the definition of beneficial use, in some prior appropriation systems water rights are transferable, subject to the assurance that the transfer does not cause harm to existing uses of water. This concept of “harm” even protects junior users. For example, if a junior water right holder located downstream from an irrigator with a senior water right relies on return flow from the upstream irrigation use, the senior user may not be allowed to transfer the senior water right to a new diversion point downstream of the junior user. If the senior user were permitted to do so, in dry periods the junior user would lose access to water to which he or she was previously legally entitled to divert, and would therefore suffer harm.

In Chile, water use permits become the property of the right holder upon their registration. Owners of these rights may subsequently use or dispose of the right; the rights are transferable.

In Japan, neither the River Law nor the Industrial Water Law specifies the duration of the permission to use water, although the former law does permit the cancellation, alteration or suspension of the permission (or the imposition of new conditions in certain circumstances). Additionally, as mentioned above, when a new project affords a greater public benefit than an old one, the older project may lose permission for its activities, although the new permittee must compensate the old permittee for the loss suffered.

3.5. Conditions, fees and charges

As part of the permitting system, states may impose conditions when they grant use permits, and may levy fees and charges on the use. In South Africa, for example, water abstraction licences are not unconditionally granted. The government may impose conditions such as requiring a management plan and certain management practices, or specifying the amount of water permitted or the method of abstraction. Conditions placed on permits in the U.S. State of Oregon consist of “advisories” that list limitations on the use of water based on applicable laws and operational constraints (Bastach, 1998). For example, in basins where surface water and groundwater linkages may require future regulation of water use, permittees are given permits conditioned on the possibility of future regulation or mitigation requirements. It is also now standard in Oregon for permits to require all new groundwater permittees to meter and report their use.

In Japan, the Minister of Construction may attach certain conditions when granting permission to use river water, but these must be reasonable and necessary. The Industrial Water Law also permits the imposition of certain conditions on the abstraction of groundwater: the conditions must be the least restrictive means of promoting conservation of groundwater resources in the relevant area and, as under the River Law, must not impose unreasonable obligations.

With respect to charges, daily and small-scale uses do not have to pay under Indonesian law. Other users may be subject to fees (established through regulation) based on the economic capacity of the user and the volume of water used. In Kyrgyzstan, water charges may be levied based on the government’s actual expenses for research, protection and administrative activities related to water. Water users in South Africa are subject to water use charges to recover the direct and indirect costs of water management, allocation and development activities. In Uganda, fees may be charged for both administrative costs and resource use. Water charges may be collected in Japan, the amount of which is fixed by government ordinance, although there is no provision for water charges on groundwater extraction.

IV. CONCLUSIONS

The preceding survey of legal doctrines and country experiences points to a wide variety of approaches to managing water quantity. With a few notable

exceptions, water is generally managed by the state on behalf of the public. Rights to use water are granted to public and private users by the state, with domestic and small-scale uses typically exempted.

Water is replete with public good characteristics. This argues against a pure market arrangement for the allocation of water resources and in favour of a system in which central government, water users' associations and local actors decide how water is to be allocated. The distinction made in this chapter between ecosystem water, value-added water and water-related services provides a framework for understanding that the public goods problem is most pressing for unimproved ecosystem water. As human involvement and investment in water infrastructure occurs, water takes on private good characteristics and there are increasing opportunities to manage water with market tools.

The problem of over-allocation and shortage is also addressed in a variety of ways, with some systems failing to address the question, some having extremely detailed priority systems and some relying on case-by-case negotiations to resolve allocations in times of shortage. Similarly, the duration of a permit varies from a limited span to a right in perpetuity. In some countries and states the permission to use water is transferable and in others not. Where transferability is permitted, many conditions may apply. Amongst these are the requirement to pay for water use, which the government assesses as reimbursement for various expenditures incurred in water management and administration. In the United States, the loss of permission to use water due to non-use was not contemplated in riparian systems, but in arid areas with defined priority systems the concept of forfeiture has become commonplace.

The allocation and management of water resources entails tradeoffs amongst different social, economic and environmental objectives to ensure that water is available not only where it is needed but also when it is needed by those that have the right to use it. These tradeoffs are made more difficult by scientific uncertainties over how the water cycle works in a given watershed. Even with a clear set of objectives and perfect information, the fundamental problem of optimizing allocations of water quantity would remain because of competing values and conflicting demands for a scarce resource.

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WATER RESOURCE QUALITY *

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“Water quality” is a concept grounded in relativity: the desired quality of a given water resource relates to the use desired of that resource. For example, a water resource that is intended for use as drinking water must be relatively pollution-free so that it is suitable for human consumption, whereas water that is intended for recreational purposes can be less pristine and still serve its intended purpose. Thus for water quality the key question is, “how clean is clean?”

An integral part of maintaining water quality is pollution control. Pollution can reduce the quality of water to the point of rendering it unsuitable for any meaningful human use and destructive to broader and dependent ecosystems. Pollution control is therefore fundamental to the use, protection and preservation of water resources.

This chapter considers the challenge of maintaining water quality through pollution control or, in the case of already polluted waters, recovering water quality. It begins by reviewing the complexity of freshwater systems and the nature and sources of water pollution. It describes the effects of pollution on humans, animals and ecosystems. The chapter then looks more closely at two principal categories of water pollution – “point source” pollution (pollution conveyed to water systems by discrete sources) and “non-point source” pollution (pollution without a discrete source), and suggests actions and policies that can help prevent and alleviate both kinds.

Although water pollution control can be a technical subject, this chapter does not attempt to catalogue the various means and methodologies for its mitigation. Rather, it considers the social, economic and health factors relating to water pollution, the principles that tend to inform government responses to it and the tools and strategies typically deployed in water pollution control.

I. WATER QUALITY

1.1. The water cycle and water quality

As described in Chapter 2, our world’s water systems are best understood not as a series of discrete and separable water bodies but rather as a complex and inter-related network within which many natural cycles and processes are constantly at work. For example, through the cycle of evaporation and precipitation, water molecules from surface moisture become airborne and

then return to the earth as rain and snow, feeding the streams, tributaries, rivers, lakes and oceans that provided the bulk of the evaporate in the first place. Groundwater bodies are commonly inter-connected and generally both discharge to and are recharged by surface waters. These are all features of the water cycle (UNEP, 2005).

Pollution introduced anywhere in this cycle is ordinarily unconfined and amenable to distribution. Thus, when water molecules bind with air contaminants in the atmosphere, the result is precipitation that brings a pollution load back to the surface waters that it replenishes. A contaminated stream not only conveys pollution to other downstream surface water bodies but can also provide a polluted recharge to an underground aquifer. And polluted groundwater not only presents a risk of pollution migration to other parts of the underground system but can also carry pollution to the surface water bodies to which it discharges. A meaningful approach to ensuring water quality, therefore, must appreciate these synergies.

After the eventual recognition of the human and environmental implications of water pollution over the last century, considerable progress has been made in understanding how fresh water systems function and in developing control strategies for protecting them. Yet, success in deploying these strategies has been uneven at best. Water quality all too often turns on the sufficiency of the resources needed to develop and implement the necessary protections and on the political will needed to transform an emerging concern into a societal priority. Fortunately, there is today a substantial body of collective experience that nations may draw upon in designing water pollution control systems, which should ease the resource burden. With increased understanding of the true cost of degradation of fresh water resources, water pollution is no longer seen as an insignificant second-tier political concern. Rather, it is appropriately understood as integral to a nation's long-term sustainability and survival.

1.2. The surface water/groundwater interface and water quality

Groundwater serves as a major source of the world's drinking water. Identifiable and reasonably well-defined groundwater bodies are known as aquifers, which are typically porous geologic formations – composed of such materials as sand, gravel or limestone – which contain water. An aquifer is ordinarily not a confined system, but rather is subject to various externalities, such as recharge from surface water bodies (which are often more

contaminated); migration of water from other polluted groundwater systems; and “leaching” of contaminants and wastes from ground surfaces down through the soil and into the aquifer (UNEP, 2005).

Accordingly, although the quality of groundwater is frequently better than that of surface water, its quality is highly sensitive to activities that take place on the surface. For example, as a result of manufacturing and agricultural activities, groundwater resources often become contaminated with heavy metals, nutrients and chemical compounds used in fertilizers or pesticides. The management of wastes – both ordinary municipal solid waste and hazardous waste – is also of great importance to the preservation of groundwater quality. For example, it is a common waste management practice to dispose of such waste simply by burying it. The assumption is, “out of sight, out of mind.” But when solid and hazardous wastes are buried without proper attention to such protective devices as landfill liners, leachate collection systems and groundwater monitoring wells, groundwater resources can be put at serious risk of contamination.

Once an aquifer has become contaminated, restoring it often requires a complex process of removing the surface or sub-surface source of the pollution, pumping the groundwater to the surface where it can be treated and then recharging the aquifer with treated, clean water. This kind of “pump and treat” remedy can take years to execute and can be quite costly, making prevention of groundwater pollution in the first instance an acute priority.

1.3. Watershed management and water quality

The term “watershed” describes the total land area from which water drains into a particular stream or river. Watersheds can be large or small. Every stream, tributary or river has an associated watershed, and small watersheds are often parts of larger ones.

Inherent in the watershed concept is the idea of “connectivity” – the physical connection between tributaries and rivers, between surface water and groundwater and between wetlands and both surface water and groundwater. Water moves downstream and therefore any activity that affects water quality at one location affects locations downstream as well. For this reason, a serious approach to ensuring water quality requires consideration not only of

water quality at a particular location of concern, but also upstream problems that may have downstream impacts.

This will require special attention where water bodies or watersheds are not contained within national borders. Arrangements typically play out according to principles of international law and international agreements among the involved states. According to the principle of equitable use, states are free to exploit resources within their territories, but must do so in a way that does not impair the resource rights of other states. In the pollution control context, this would mean that upstream states have a responsibility to downstream states to avoid degradation of shared water resources. Equally, the principle of cooperation holds that states should work in a consultative and collaborative manner to reduce and control the pollution of shared watercourses by, amongst other things, establishing common water quality objectives and harmonizing national laws and policies relating to such watercourses.

II. WATER POLLUTION

2.1. Defining “pollution” in the water context

The common understanding of the term “pollution” is the introduction into the environment, directly or indirectly, of substances that change environmental conditions and result in harmful effects, either because of their nature or quantity. Another definition refers to the impairment of the designated use of a water body or resource caused by changes in water characteristics.

Not all pollution is anthropogenic (i.e. generated by human activity); some of it occurs naturally as a result of natural formations and events that release substances that affect water quality. For example, naturally occurring pollution can come from fires, volcanic eruptions or the drowning of large animals. Some groundwater is contaminated by naturally occurring pollutants such as arsenic or salt. Such natural pollution cannot be regulated, although governments have often attempted to develop response mechanisms to limit its impact.

Anthropogenic pollution is the most important concern from a water management standpoint because it is both subject to control and a major source of water quality problems. Not all anthropogenic pollution is harmful,

however. The environment has the capacity to assimilate pollution up to certain limits, and it is only when these limits are exceeded that pollution is cause for concern. Put another way, the presence of a pollutant in a water body does not necessarily mean that the water body is polluted. It depends on both the concentration of the pollutant and the intended water use.

Anthropogenic pollutants generally fall into two categories. “Stock pollutants” are pollutants that accumulate with little or very slow degradation because the capacity of the environment to assimilate them is very small (i.e. they persist in the environment) and “fund pollutants” are pollutants that, by contrast, decompose and thus do not as readily tax the assimilative capacity of the receiving stream. An example of stock pollutants would be inorganic chemicals and heavy metals that cannot be removed by natural processes, whilst an example of “fund pollutants” would be human and animal wastes. Management of stock pollutants is typically preventative, in the sense that the introduction of such substances into the environment should be avoided or reduced. Management of fund pollutants often focuses both on prevention and on creating conditions that enhance degradation or allow natural degradation to convert the pollutants into an innocuous form.

2.2. Types of water pollution

Anthropogenic water pollution can be grouped into three general pollution categories: physical, organic and toxic. Each of these is discussed below and also set out in Box 6.1.

Physical. Physical pollution consists of pollution that materially changes the physical characteristics of a water body. Some pollutants dissolve in water whilst others, composed of larger particles, remain suspended in the water. Eventually, these particles settle and form silt or mud on the beds of water bodies, decreasing the depth of the water body and affecting aquatic life. This sedimentation is one example of physical pollution. Another form of physical pollution is the discharge of objects and solid wastes (e.g. plastic, paper) into water bodies. Such pollution impairs the landscape, obstructs waterways and can be harmful to wildlife.

Another type of physical pollution is thermal (hot water) pollution. Thermal pollution occurs when water used for cooling in power or industrial plants is discharged heated into a water body. Conversely, when water is taken from a water body – for example, diversions from a river for use in irrigated

agriculture – the remaining water body will have a smaller volume and will therefore heat more rapidly (depending on solar radiation and ambient temperature). Thermal pollution increases the temperature of water and can lead to both a decrease in the dissolved oxygen level in the water and an increase in the biological demand of aquatic organisms for oxygen. The results are commonly a reduction in the number of organisms that can live in the water body and disruption of the water body's ecological balance, because some plants and animals are killed whilst others' growth is stimulated.

Similarly, cold water pollution can seriously affect the water environment. Releases of cold water occur downstream from dams (because water is discharged from the bottom of the reservoir rather than the surface) and can have the following negative consequences: elimination of native fish; loss of recreational uses; and proliferation of non-indigenous cold water fish, resulting in additional pressure on native species from predation and competition for food sources and habitat.

Box 6.1 - Types of Pollutants and Their Origins

<i>Type</i>	<i>Origin</i>
Physical	land surface erosion litter and mismanaged solid waste organic matter runoff from buildings or construction sites diversion of flow from rivers storage of water behind dams
Organic	organic matter fertilizers sewer overflow detergents animal and human wastes
Toxic	pesticides herbicides runoff from buildings and roads (oil) detergents

Organic. Organic pollution consists of organic wastes and compounds. As noted above, depending on the nature of the organic pollutant, freshwater bodies can often assimilate a certain amount of organic pollutants without serious effects. However, left unabated, organic pollution can alter the ecological balance of the water body. Organic pollution most frequently comes from human or livestock wastes and agricultural fertilizers. Mild organic pollution usually reduces biodiversity by increasing the populations of organisms that feed directly on organic materials. Organic pollution can also cause blooms of algae. The abundance of organic material can also affect the bacteriological population, in that bacteria that were previously limited in number due to a lack of food undergo a population explosion. These bacteria can reduce the amount of available oxygen, particularly in slow-moving water. If severe enough, the lack of oxygen (a condition known as hypoxia) can kill fish and other aquatic life.

Toxic. Toxic pollutants are those compounds and contaminants (such as some chemicals, solvents, acids, alkalis, heavy metals, pesticides and oil) that are poisonous to humans, animals or the environment. They cause toxicity, which occurs when a living organism experiences detrimental effects upon exposure to a substance. If toxicity is acute, short-term exposure produces the detrimental effect; if toxicity is chronic, the detrimental effects arise only after prolonged or continued exposure. If chronic toxicity leads to abnormal cell growth, the substance is known as a “mutagen” and may even cause cancer. In terms of human health, chronic toxicity may cause rashes and irritations, cancer and a reduction in reproductive capacity amongst individuals who are exposed to toxic water pollution.

Although all toxic pollution is cause for concern, two classes of toxic pollutants bear particular note: persistent organic pollutants (POPs) and heavy metals. POPs are toxic substances composed of organic (carbon-based) chemical compounds and mixtures that persist in the environment and pose a risk of adversely affecting human health and the environment. Through “bioaccumulation” or “biological magnification”, their concentration increases at higher levels in the food chain and thus they can be very harmful to human health.

Heavy metals naturally occur in soil and water, but their worldwide production and use by industry, agriculture and mining have released large additional amounts into the environment. Water pollution related to metal production and use, including the release of acids from mining wastes, is a

problem in many of the world's mining and metal processing regions. Elevated levels of some metals, such as lead and mercury, are also found around many cities, particularly if they are downstream or downwind from metal smelters and coal-burning power plants (UNDP, 1999). Some of the metals of greatest concern for human health are lead, mercury, arsenic and cadmium. Many other metals – including copper, silver, selenium, zinc and chromium – are highly toxic to aquatic life.

2.3. Sources of water pollution

Sources of water pollution generally divide into two classes: point sources and non-point sources. Point source pollution is pollution that comes from discrete and identifiable points (or outfalls) that discharge directly into a hydrologic system. Such discharge points are usually associated with industrial activities and municipal sewerage plants. The presence of pollutants in point source wastewater harms the quality of the receiving water body and limits the possible uses of that resource.

Non-point source pollution is pollution delivered to water systems through runoff, infiltration and other unchanneled means. It often derives from multiple sources or from sources that are not readily identifiable and enters the freshwater system as a result of natural processes such as rainfall or melting snow. Runoff from all kinds of surfaces – including industrial sites, agricultural areas and municipal areas – carries various pollutants into water bodies. Pollution can also be delivered by rain or snow that has bound with pollutants in the atmosphere.

Three anthropogenic activities – industry, agriculture and urban settlement – are common sources of point source and non-point source water pollution and are described in detail below.

2.3.1. Industry

Primary and secondary industrial activities – the extraction of raw materials and their processing – are responsible for the emission of numerous kinds of pollutants, including grit, phosphates, nitrates, mercury, lead, caustic soda and other sodium compounds, sulphur and sulphuric acid, oils and petrochemicals. In addition, many manufacturing plants discharge undiluted corrosives, toxins and other noxious by-products. The construction industry discharges slurries of gypsum, cement, abrasives, metals and hazardous

solvents. Another pervasive group of contaminants used and discharged by industry is synthetic chemicals, such as polychlorinated biphenyl (PCB) compounds and components of lubricants, plastic wrappers and adhesives.

Mining consumes, diverts and can seriously pollute water resources. The impact of mining on water resources depends on a variety of factors, such as the composition of the minerals being mined, the type of technology employed and the skill, knowledge and environmental commitment of the mining company in question. Mining produces a large amount of different wastes, all of which need to be managed properly. Waste rocks and mine tailings, for example, often contain acid-generating sulphides, heavy metals and other contaminants, and are often stored in free-draining areas or in containment areas that are not well monitored or controlled (classic non-point sources). These areas can be a source of pollution for surrounding water resources, as they can leach through the soil or be washed away by runoff.

In the manufacturing sector, wastewater typically requires treatment before it can be discharged into freshwater systems. Such treatment must be carried out using appropriate technologies and in compliance with government directives and regulations. Industrial plants often have their own treatment facilities. They also frequently rely on publicly owned treatment works (POTWs) for the treatment of their wastewater, discharging to water resources via a so-called “indirect discharge”. The major risk of indirect discharge is that receiving POTWs may not be equipped to deal with specific pollutants suspended or dissolved in industrial wastewaters. These may simply pass through the POTW or upset the system’s ability to treat other waste. The net result is polluted water discharged by the POTW.

Industrial activities also release gases and airborne particulate matter that can result in air pollution. As noted, this atmospheric pollution may eventually pollute water resources through deposition or precipitation. Industrial activities may also cause thermal pollution, since industrial processes need effective systems for chilling machinery during and after use, and water is commonly used for this purpose.

Finally, runoff from industrial areas can carry pollutants into the freshwater system. The storage and disposal of hazardous waste generated by industrial processes is one common source of such pollution. Failure to handle and store such waste properly can result in dangerous discharges reaching

freshwater systems through storm sewers and floor drains and through other direct and untreated discharges. Cleaning materials used in industrial operations also often contain harmful constituents and can themselves present problems when washed into water bodies.

2.3.2. Agriculture

The greatest demands placed on the world's water resources come from agriculture, which is also a major cause of water pollution. Agricultural pollution is most commonly a non-point source, in that it often runs off from large areas of land rather than being channelled through discrete conveyances. However, agricultural operations sometimes include identifiable point source discharges, particularly in concentrated livestock operations.

The main water quality problems associated with agriculture are salinization, nitrate and pesticide contamination and erosion that causes an increase in suspended solids in rivers and streams and siltation. Pollutants originating from agricultural activities include nutrients, heavy metals, pesticides, sediments, oxygen demand substances and pathogens.

The use of fertilizers (often composed of phosphorus, nitrogen and potassium, manure, sludge, irrigation water or crop residues) to enhance production can contribute negatively to water quality. When applied in excess of plant needs, such nutrients can wash into aquatic systems where they may cause excessive plant growth that can kill fish and other wildlife, create a foul taste and odour in drinking water and reduce recreational opportunities (Verona *et al.*, 2000). The same is true of pesticides, herbicides and fungicides, which can enter and contaminate water through direct application, runoff, wind transport and atmospheric deposition. Because they are specifically designed to kill living organisms, these chemicals are equally lethal to non-target fish and wildlife, poisoning food sources and destroying animal habitats.

Although irrigated agriculture is an essential component of any strategy to increase global food supply, irrigation itself can present a number of challenges to water quality. Problems such as waterlogging, salinization and erosion can damage irrigated areas, rendering them unsuitable for productive agricultural use and creating water quality concerns for surrounding water bodies. In particular, if improperly managed, irrigation can contribute to

erosion and siltation and cause downstream degradation of water quality due to the effects of salts, agrochemicals and harmful leachates. Irrigation return flows, which collect runoff from cultivated areas, can carry high concentrations of pesticides, herbicides and nutrients to nearby waters.

Inefficient irrigation can pose other water quality problems. In arid areas, for example, where rainwater does not carry residues deep into the soil, excessive irrigation can concentrate pesticides, nutrients, disease-carrying micro-organisms and salts in the top layer of soil, where they pose a greater risk of reaching water systems via erosion and runoff.

The accumulation of pesticides and agricultural fertilizers in local watersheds has serious health consequences for farming families, including high rates of cancer and foetal malignancies or miscarriages. It can also kill wildlife and disrupt the ability of animals living in the watershed area to reproduce. The employment of wastewater for irrigation purposes, although an important strategy in water-scarce regions, can also increase the amount of contaminants that reach water resources when the wastewater is not adequately treated prior to use. The human health effects of these and other types of pollution are discussed at greater length in the next section and in Chapter 8.

Animal farming also presents serious water quality challenges. Animal husbandry generally requires pastureland, feed lots and facilities for keeping animals, and commonly generates significant amounts of organic waste which can pollute both surface water and groundwater resources. Although confining large numbers of animals to areas or lots allows farmers and ranchers to efficiently feed and maintain livestock, these areas often become concentrated sources of animal waste. Runoff from poorly managed facilities can carry pathogens (bacteria, viruses, parasites), nutrients and oxygen-demanding substances that can contaminate fishing areas and pose other water quality problems. Groundwater can also be contaminated by seepage from such facilities.

Silviculture and other forest management activities also present water quality concerns. Since forests stabilize local soils and hydrology, forest management – i.e. the felling or clearing of trees and brush in woods and forests to allow for agricultural activities and the harvesting of trees for wood products – can contribute significantly to soil erosion, increase siltation in local water resources and generally affect the quality of surface water runoff.

Aquaculture is also a significant source of water pollution. Waste from fish farming, including fish faeces and unconsumed feed, can contain excess amounts of nitrogen, phosphorus, ammonia, bacteria and industrial chemicals.

2.3.3. Urban areas

Urban areas have profound implications for watershed management and often significantly pollute water resources. Urban structures frequently interfere with natural hydrologic processes by creating barriers to groundwater movement and affecting groundwater recharge. Non-industrial urban water pollution takes two main forms – discharges from municipal sewerage systems and runoff from urban surfaces – but solid waste disposal and transportation are other important urban sources of water pollution.

Modern cities typically have systems for collecting and channelling wastewater from private dwellings, businesses and public buildings. To be environmentally safe, this municipal wastewater must be treated before being discharged into freshwater systems. There are three general classes of treatment for municipal wastewater: primary treatment, which typically includes grit removal, screening, grinding and sedimentation; secondary treatment, which ordinarily entails oxidation of dissolved organic matter by means of using biologically active sludge that is then filtered off; and tertiary treatment, which employs advanced biological methods for nitrogen removal and various advanced chemical and physical methods such as granular filtration and activated carbon absorption.

The existence and enforcement of regulations governing wastewater discharge are an important factor in determining the extent of treatment in a given urban environment. The financial health of the local government and the availability of financial assistance such as grants or bonds for the construction and maintenance of treatment facilities also play an important role in how extensively urban wastewater is treated.

Even reasonably well-developed and maintained treatment systems can contribute to pollution problems in freshwater systems. For example, detergents and cleaners used in private dwellings, businesses and public offices often contain phosphorus compounds that are not fully removed by treatment systems. These phosphorus compounds act as nutrients when they reach water bodies. Further, industrial wastewater conveyed to municipal

treatment facilities (indirect discharges) may contain constituents that fall outside the treatment efficacy of a given plant and thus pass through the facility untreated, potentially interfering with the biological processes upon which secondary or tertiary treatment depend.

Urban runoff is another significant source of water pollution, especially in developed countries. In all urban areas (in particular where construction is taking place), sediments are swept up by rainwater or collected in underground or surface storm water channels and then discharged into water bodies. In residential areas, rainwater and storm waters wash over concrete, lawns, cars and buildings, carrying numerous types of pollutants to the freshwater system. Urban runoff in residential areas typically carries fertilizers and pesticides used for lawn care, and also washes dust, heavy metals and oils from the streets into the freshwater system.

Municipal solid waste and garbage are commonly collected and deposited in solid waste disposal sites which, if improperly constructed or maintained, can be a significant source of water pollution. As with industrial waste disposal sites, in the absence of landfill liners and leachate detection and collection systems, natural agents, especially precipitation, can cause pollutants rich in organic substances and toxic chemicals to dissolve in groundwater and leach from solid waste disposal sites. Solid wastes and trash not properly collected and managed may also be carried into freshwater systems by surface water runoff.

Finally, urban areas contribute to water pollution through sources related to transportation. Airborne chemical emissions from transportation activities settle into freshwater systems and contribute to water quality problems. Groundwater and surface water alike receive a considerable amount of pollution from such transportation-related problems as oil and gasoline spills, application of de-icing chemicals, road salt, herbicides, impregnation chemicals (i.e. chemicals used to protect and extend the functional life of road surfaces) and accidental discharges from chemical containers. Runoff from roads and parking lots carries litter and sediments together with oil and chemicals that eventually reach water bodies.

2.4. Effects of water pollution

2.4.1. Human health effects

Water serves as a ready pathway for exposure to numerous microbial and contagious diseases. The three major pathways by which water pollution affects human health are direct consumption, indirect consumption and dermal (skin) contact with polluted waters. Because humans need water for drinking, personal and domestic hygiene and food preparation, these are the primary pathways for direct consumption of water pollutants. When people eat animals and plants that have been exposed to pollutants that bioaccumulate, they indirectly consume these pollutants. Dermal contact occurs mainly in people who rely heavily on water for their livelihoods. For example, fisherfolk spend their days in the water, and water is necessary for all agricultural and animal husbandry activities, through which farmers may be exposed to multiple pollutants.

Vulnerable populations, such as children, pregnant women and the elderly, are often most affected by water pollution. Young children, because they have faster metabolisms than adults and do not have fully developed immune systems, generally have the highest risks when exposed to toxic chemicals. The ingestion of polluted drinking water and consumption of food grown with polluted water have been associated with learning impairments and hyperactivity in children. They can also lower sperm count in men and cause immune system disorders, cancer and genetic damage.

Water pollution is particularly problematic in the developing world, where millions of people obtain water for drinking and sanitation from unprotected streams and ponds. Organic pollution is frequently the cause of illness. If wastewater is not properly treated, for example, or if families and communities bathe and wash in water sources contaminated with animal or human excreta, individuals are exposed to disease vectors. Some of the most significant water-related infectious and parasitic diseases include hepatitis A, diarrhoeal disease (such as dysentery), cholera, typhoid, roundworm, guinea worm, leptospirosis, schistosomiasis, salmonellosis and cryptosporidium. The most prevalent and deadly water-associated health problem is diarrhoea. In developing countries, diarrhoeal diseases cause millions of deaths and episodes of illness annually. Although it was traditionally believed that most diarrhoea was caused by faecal-contaminated drinking water, recent

epidemiological studies have shown that in some settings other domestic uses of water can pose an equivalent risk (Van der Hoek, 2001).

As stated above, the runoff from industrial and agricultural activities often finds its way into water bodies that are important sources of drinking and bathing water for urban and rural families. Surface and ground waters act as sinks or transportation routes for chemicals, heavy metals and organic substances that can produce cancers, chronic and systemic illnesses, malignancies and birth defects and impair immune system functions (Wu *et al.*, 1999). For example, mercury and lead leaching into the groundwater from industrial activities can cause nervous disorders and diminished mental capacity, and nitrates used in agricultural activities have been implicated in blood disorders.

Nitrates offer an interesting illustration of the human health challenges associated with poor water quality. Nitrates from fertilizers and from human and livestock waste leach into the soil and become groundwater pollutants in many regions. Nitrate itself is a relatively non-toxic substance; however, bacteria in the environment and in the human body can convert nitrate to nitrite, which is very harmful. Infants under six months old (whose digestive systems both secrete lower amounts of gastric acid and have high pH levels), as well as elderly adults (who may have a diminished capacity to secrete gastric acid), can experience bacteria proliferation which can accelerate the transformation of nitrate to nitrite. Nitrite, once in the blood, serves to oxidize the iron in the haemoglobin of red blood cells to form methaemoglobin, which lacks haemoglobin's oxygen-carrying capacity. When methaemoglobin levels are elevated in infants, a condition known as methaemoglobinemia, often referred to as "blue baby syndrome," can result, since the blood lacks the ability to carry sufficient oxygen to individual body cells. Concern over this nitrate-to-nitrite phenomenon led the United Nations Development Programme to assert that nitrate pollution will likely be one of the most pressing water quality problems in Europe and North America in the coming decade, and will become a serious problem in other countries such as Brazil and India if present trends continue (UNDP, 1999).

Polluted water affects people across the socio-economic spectrum, but the poor suffer disproportionately. In rural areas in developing countries, families rely on streams, wells and lakes for all of their water needs and yet this water is often untreated, unfiltered and untested. Small-scale rural farmers may have little choice but to use an array of fertilizers and pesticides

to grow enough food to support their families. These chemicals find their way into community water sources, with harmful results. Certain pesticides such as DDT are not only toxic, but can alter chromosomes, and the effects are being observed generations after the original exposure. PCBs have been determined to cause liver and nerve damage, skin eruptions, vomiting, fever, diarrhoea and foetal abnormalities. Unfortunately, communities living downstream from an industrial operation that leaches pollutants into the watershed area may have no other option than to continue to use the water that flows through their village.

2.4.2. Environmental effects

Water pollution impairs not only human health but also the health of plants, animals and ecosystems. Changes in the chemical and physical characteristics of water can degrade the habitats of indigenous animals, cause disease, infertility and death in various animal species (particularly fish and amphibians) and can result in severe ecosystem damage.

Perhaps the most common and significant environmental hazard related to pollution in water bodies is the lowering of the level of dissolved oxygen in a water body. The health of water bodies is measured in terms of dissolved oxygen (DO) and of biological oxygen demand (BOD). The DO in water comes from the oxygen in the air and from the photosynthesis processes of aquatic plants: its level is affected by the turbulence of water as well as by its temperature. Because colder waters contain more DO, thermal pollution can affect DO levels. If water temperature rises as a result of thermal pollution, the level of DO tends to fall.

The more significant impact on DO, however, is caused by the presence of biodegradable wastes. Such wastes are broken down and used as food by micro-organisms such as bacteria. In digesting their "food", bacteria consume oxygen, and the level of DO accordingly decreases. Once the oxygen is depleted, other bacteria that do not need dissolved oxygen take over. Whereas aerobic (or oxygen-dependent) micro-organisms convert the nitrogen, sulphur and carbon compounds that are present in the wastewater into odourless oxidized forms (such as nitrates, sulphates and carbonates), anaerobic micro-organisms produce toxic and noxious substances such as ammonia, amines, sulphides and methane.

Phosphorus and nitrogen are necessary for plant growth and tend to be plentiful in untreated and poorly treated wastewater. Added to lakes and streams, they can cause nuisance growth of aquatic weeds, as well as “blooms” of algae. This can cause several problems. While the blooms are alive, photosynthesis increases dissolved oxygen. But when the algae and weeds die and become biodegradable material, this can increase BOD and contribute to a reduction in DO levels.

Moreover, such nutrients can spur the excessive growth of microscopic floating plants. This process, known as eutrophication, has a range of impacts.¹ The layer of microscopic plants can veil the water surface, making it difficult for larger submerged aquatic vegetation to get the light they need. This can lead to the death of light-deprived plants and to their subsequent decomposition, which consumes yet more oxygen in the water. Apart from its impact on plant life, eutrophication may also render a body of water uninhabitable for most other life forms, and may lead to the death of the water body. This phenomenon most seriously affects still water bodies such as lakes and ponds, but the excessive growth of aquatic plants can also be a problem in rivers, where it can cause siltation, blockage of channels and, in some cases, even de-oxygenation.

In addition to thermal pollution, which, as noted, can render a water body unsuitable for certain species whilst promoting the proliferation of others, excessive erosion is another type of physical pollution which can pose a significant threat to environmental health, particularly in relation to siltation. Silt carried by runoff accumulates in rivers and in lakes, affecting their flow and their capacity. Moreover, silt often contains pollutants such as nitrates or toxic chemicals, which can affect water quality.

Atmospheric pollution also contributes to environmental effects in water resources. The emission of sulphur and nitrogen oxides, along with other gases, can cause so-called acid rain. Rainfall and dry deposition carries these contaminants into water bodies. Indeed, acid rain can effectively destroy still water bodies, leaving them a distinctive clear blue and completely devoid of life. Acid rain can also affect flowing water, although not with the same measure of destructiveness.

¹ Eutrophication also has implications for human well-being and health. Algal blooms are the source of algal toxins, which are associated with increased incidence of liver and other cancers. If the water is used as a drinking water source, algae can also clog filters and impart unpleasant tastes and odours to the treated water.

III. WATER POLLUTION CONTROL

The primary animating principle for pollution control is prevention, meaning that avoiding pollution is preferable to having to remediate its effects. Policies should therefore be aimed at managing pollution sources in a way that constrains their post-discharge impact on water resources. The next sections discuss first the control of point sources and then non-point sources of water pollution.

3.1. Controlling point sources of water pollution

3.1.1. Why control point sources?

Point source discharges to water bodies are a consequence of human activity. Typical point sources include factories, mines and other discrete industrial or agricultural activities that emit pollutants into the local watershed. The key variables regarding point sources are *what pollutants* they convey to receiving waters and *how much* is conveyed. Because point sources deliver wastewater in concentrated form, they can be quite destructive if the pollution is insufficiently diluted or untreated. It is because of both their destructive potential and the relative ease with which they can be identified and managed that point sources are most often the first objects of water quality regulation. It should be noted, however, that not every point source discharge is undesirable. From a wastewater management standpoint, the process of capturing and channelling wastewater through discrete conveyances or point sources can be a positive phenomenon: wastewater, in this form, is eminently more treatable and measurable than when discharged via non-point sources. Point sources can also play a positive role in diminishing erosion and preventing siltation – common problems associated with non-point source pollution.

3.1.2. How are point sources currently addressed?

The responsibility for the control of point source pollution has been seen as resting principally with governments, which must enact and enforce regulations and oversee the implementation of pollution control strategies that protect the interests of their citizens. As discussed in Chapter 3, governments use legal and regulatory instruments to implement point source pollution controls. These instruments tend to consist either of command and control or market-based mechanisms such as economic incentives and

disincentives to enforce the compliance of factories, mines and other discrete pollution-generating facilities with pollution standards. States may also implement public education and awareness campaigns as part of their efforts to control point source control pollution.

Several preliminary steps are necessary before controls can be implemented on point source pollution of water resources (see Box 6.2). Each is reviewed below.

Box 6.2 - Preliminary Steps to Controlling Point Sources of Pollution

1. assessment of the ambient condition of the water body
2. determination of desired uses of the water body
3. identification of point sources that contribute pollution to the water body
4. definition of effluent requirements needed to maintain or achieve desired water quality characteristics (through technology-based standards or water quality standards)

Assessment of the ambient condition of the water body at issue. Whether point source control programmes are implemented through government regulation or through less formal mechanisms, the starting point is much the same: water quality assessment. This requires an inventory of pollutants present in the water body. Although this is site-specific, countries that have few resources to devote to research can consult inventories of pollutants (and their common sources) developed at international level. For example, the United Nations Environment Programme established the International Register of Potentially Toxic Chemicals in 1977, with the primary purpose of making information on chemicals substances widely available.

Determinations of ambient water quality are often guided by water quality indices, which are designed to indicate the “healthiness” of water. Indices fall into two primary categories: (1) water chemistry-based indices, which assess water quality based on nutrient levels, microbiology, dissolved oxygen and occasionally metals; and (2) effects-based indices, which attempt to gauge water quality by reference to the biological reaction to aquatic pollutants (FAO, 1996). Water managers use these indices to assess the potential for ecosystem dysfunction, to help identify possible sources of pollution and to guide development of pollution control programmes.

Determination of desired uses of the water body. Another step preliminary to control of point source pollution is identifying designated uses for given bodies of water, a task often assigned to state regulatory agencies. Designated uses are usually expressed as desired water attributes (e.g. usable as potable supply, or for fishing, agriculture, bathing, swimming or other recreation), and are ordinarily influenced by both historical use patterns and existing water quality. If, for example, a water body has historically been used for fishing, then fishing will ordinarily be included among its designated uses and pollution controls will be calibrated to this objective. If a water body is not fit to be used for drinking water, then potability is less likely to be included as a designated use. However, water quality goals may anticipate or aim at an improvement in water quality rather than simply maintaining the status quo. Thus, for example, if historical use patterns include fishing but existing water quality is insufficient to allow it, then fishing may be included as a designated use and pollution controls may be calibrated to restoring the water body to the point that it can support safe fishing.

Identification of point sources that contribute pollution to the water body. Once a water body and its pollution sources have been identified, and designated uses for the water body have been determined, the next step is identifying the point sources that are contributing pollution to the water body.

Definition of effluent requirements needed to maintain or achieve desired water quality characteristics. The process of setting effluent standards requires identifying measures that are (1) technically feasible for the activity in question and (2) essential to achieving water quality objectives for the receiving water. The first are known as technology-based standards whilst the latter are water quality standards.

- technology-based standards

Technology-based standards reflect two approaches. The first is pollution prevention, focusing on manufacturing (or other) processes with the objective of applying “cleaner” technology to reduce the amount of wastewater generated in the first instance. The second is pollution control, generating standards based on so-called “end of the pipe” technologies that neutralize or ameliorate pollution after wastewater generation but prior to discharge.

It is common for regulations to require point sources to use the “best available technology,” or BAT. The definition of what constitutes the “best” available technology for any given waste-generating process varies by nation, but international guidance is available.² The concept of BAT commonly includes consideration of economic feasibility and is sometimes expressed as the “best available technology not entailing excessive cost”, or “BATNEEC”. Under this formulation, governments take into consideration the costs associated with the installation of new pollution control devices or the upgrading of existing facilities and operating methods, attempting to strike a balance between environmental benefits and financial costs.

A related formulation is the so-called “best environmental practice”, or “BEP” standard. As in the case of BAT, the final responsibility for deciding what constitutes BEP rests with national governments. However, general guidelines to be considered for the definition of BEP have also been elaborated at the international level.³

A third formulation is the “best management practice” (BMP) standard. This type of standard typically focuses on how technology is managed and operated, as opposed to the choice of technology in the first place. Establishing BMP can be challenging, but it can be of considerable utility in preventing water pollution. BMP can, at least in theory, be elaborated for every activity that contributes to water degradation, from industry to agriculture. As with all of the approaches to technology-based standards, BMP for a given activity is generally established at the national level.

The disadvantage of technology-based standards is that they are usually divorced from consideration of the pollution levels in the receiving water body and how those levels relate to the desired uses associated with it. This is because they focus on the pollution source rather than the receiving waters. For this reason, technology-based standards are frequently coupled with water quality standards that take into account the quality and intended uses of the receiving waters.

In the United States, for example, point sources are required by the Clean Water Act both to meet technology-based requirements and to implement additional measures necessary to avoid a violation of water quality standards

² See e.g. Helsinki Convention, Annex II, 2002.

³ *Id.*

in the receiving water body. Another example is the European Directive on Urban Waste Water Treatment (UWWT) of 1991, enacted to protect the environment from the adverse effects of sewage discharges and to ensure that all significant discharges are treated before being released into receiving waters. The UWWT sets uniform effluent standards (or percentage reductions in pollutant concentrations) for discharges from urban wastewater treatment works serving a population equivalent of 2 000 or more persons. These standards are flexible, however: the classification of receiving waters is used as the basis for defining the treatment level required for the wastewater.

Another concern with technology-based standards is their revision. The assumption underlying a BAT, BEP or BMP approach is that standards will be revised as pollution control technologies and techniques improve over time. In practice, however, in many jurisdictions these standards remain static. This is due in part to the cost to government of examining and revising standards, and in part to the cost to industry of changing technology (and hence their strong resistance) because of capital already invested in treatment technologies.

- water quality standards

In contrast to technology-based standards, water quality standards (WQS) relate to the characteristics of water bodies, particularly their capacity to assimilate certain substances (or concentrations of substances). WQS are intended to ensure that water quality is sufficient to allow for designated uses and are typically expressed as concentrations of pollutants that cannot be exceeded without impairing water quality. Water quality standards rest on certain basic assumptions, most notably that the environment has a quantifiable capacity to accommodate contaminants. WQS are usually calibrated to the highest designated use, i.e. the use requiring the most pristine conditions. The WQS approach typically considers not only the effects of an individual discharge but also the combination of the range of different discharges into a water body (Helmer and Hespanhol, 1997).

WQS are developed taking into consideration the relative volume of effluent, the volume of the receiving watercourse and any dilution and degradation. Standard setting involves calculating the upper limits of allowable contaminant concentration in the effluent that will permit the standards to be met under all likely conditions. These upper limits are then used to fashion facility-specific effluent limitations which are tailor made for the

conditions surrounding a particular outfall. Limits for similar types of facilities vary throughout a country based on local water quality conditions and designated uses (Helmer and Hespanhol, 1997).

WQS may be set either at the national, regional or local level. Where national WQS have been adopted, local standards typically have to meet (and may exceed) those national standards. Because WQS-based effluent limitations are so location-dependent and variable, developing them can be quite resource-intensive, as can monitoring waters for compliance with the standards. Nonetheless, WQS-based effluent limitations represent the surest means of ensuring that water quality objectives are met, and thus are well worth the investment where resources permit.

3.2. Existing weaknesses in controlling point sources

Despite the clear benefits of an integrated approach to controlling point source pollution, in practice most water quality management systems rest on the development of generic regulatory norms without full consideration of watershed contributions and implications. Another common weakness is a lack of basic state capacity to monitor and enforce compliance with pollution control standards. Monitoring and sampling work requires both trained personnel and proper equipment. Effective enforcement follow-through requires adequate legal authority and sufficient financial and human resources to allow for the prosecution of violators. Without an effective enforcement programme, polluters have little incentive to comply.

Often, states are unable to access and administer the legal and technical tools necessary to redress non-compliance. It is a challenge for developing and developed nations to inspect polluting facilities; take water samples; analyse samples; order corrective action; seek financial sanctions sufficient to disgorge the economic benefit of non-compliance; and invoke the coercive power of the courts. Monitoring powers are particularly important, since monitoring is both the basis for enforcement in cases of non-compliance and the means of assessing the effectiveness of approaches taken to protect water resources.

3.3. Legal, market-based and informal control mechanisms

The primary legal mechanism for applying both technology-based and WQS-based effluent limitations at the facility level is a permitting or licensing

regime. Such regimes typically forbid pollution without a permit or licence that dictates the applicable effluent restrictions. Beyond establishing effluent limits, discharge permits commonly impose monitoring obligations to ensure compliance with limits, and often require periodic reporting to government agencies regarding monitoring results. Recognizing that effective monitoring and enforcement programmes can be resource-intensive, some countries have found efficiencies through such legal mechanisms as requiring point sources to self-monitor and to periodically self-disclose any violations of pollution limits (thereby reducing the need for inspections). Other countries have empowered NGOs and citizens to bring enforcement actions in court against polluting enterprises.

Financial tools, such as economic incentives for the adoption of cleaner technologies, are also effective at reducing point source pollution. Examples of such mechanisms include incentives such as tax abatements and subsidies or disincentives such as taxes on the use of specific materials in processing.

Raising the awareness of citizens regarding water quality issues can also contribute to water quality improvement. An informed citizenry can apply pressure to encourage polluters to comply with pollution control provisions. When plants and corporations see that being “environmentally friendly” is in their interest, they may be more willing to assume the costs of pollution control. Citizens can influence polluters’ actions through their expression of purchasing power, participation in political processes, community group organizing and legal actions to enforce compliance.

3.4. Controlling non-point sources of water pollution

3.4.1. The challenge of non-point sources

Addressing pollution that derives from sources that are neither readily identifiable nor easily contained is one of the most vexing problems for water quality management. To provide one example, consider the problem of pollution that comes from parking lots. Storm water that runs over parking lots picks up (1) oils and residues that have dripped from cars’ engines; (2) oils and tars from the pavement itself; (3) substances that were on car surfaces that have been washed off by rain (not only air pollutants, but also soaps and waxes used to clean and polish cars); (4) solid wastes and litter in the parking area; and (5) contaminants deposited on the parking lots

by polluted air. All of these substances are carried into streams by the storm water and pose a serious threat to water quality.

Agriculture is one of the most common and substantial contributors to non-point source pollution. Pesticides, herbicides and fungicides are used in agriculture to kill pests and to control the growth of weeds and fungi. These chemicals can contaminate water through direct application, runoff, wind transport and atmospheric deposition. As described above, these chemicals can kill fish and wildlife, poison food sources and destroy the habitat that animals use for protective cover.

3.4.2. How are non-point sources currently addressed?

Few countries have mastered non-point source water pollution to the same extent as point source pollution, because the challenges are greater. Just as in the point source context, non-point source control necessarily begins with an assessment of water quality and a determination of the uses desired of a given water body. The next step, identifying the significance of the non-point contribution to a given watershed, is a complex process that involves analysing pollution levels in the watershed, calculating pollution loadings from point sources and then subtracting the point source contribution on a constituent-by-constituent basis, with the difference presumptively representing the non-point source contribution of pollution to the watershed. This can require extensive modelling.

Even in countries where major strides have been made in addressing point sources of water pollution, effective management of non-point sources remains a significant water quality challenge. Where the non-point sources for the watershed are identifiable, control efforts typically focus on the use of BMP for the entities responsible for the pollution. In the context of storm water management, BMP includes preventing storm water from coming into contact with problematic drainage areas; reducing the presence of pollutants on surfaces in drainage areas; and managing storm water before it is discharged into surface waters. For the parking lot example above, BMP might address such elements as parking lot construction and design, the use of disposal receptacles for solid waste and methods for containing and treating storm water runoff from parking lots before it reaches any water resources. In the agricultural context, BMP tends to focus on the manner in which pesticides, herbicides and fungicides are stored and applied, as well as

mandating mechanisms for channelling and treating agricultural runoff and discouraging the overuse of such chemical compounds.

3.4.3. Existing weaknesses in controlling non-point sources

There are several barriers to effective management of non-point source pollution. First, as noted above, it is difficult to determine the non-point source contribution to water quality problems and to identify the specific contributions of individual non-point sources. Without such identification and determination, effective control is a challenge.

Second, even when “sources” are identifiable, the root causes of the contamination associated with those sources are often substantially attenuated from the discharge itself. Runoff from a highway is an example. Although the source of the runoff may be clear, many of the contaminants within the runoff are by-products from the trucks and automobiles that use the highway, and the production of those by-products is influenced by characteristics of automobile lubricants, the design of automobile engines, the composition of soaps and waxes used on cars, etc. Similarly, in the agricultural context, a complete answer to the problem of non-point source pollution requires a focus on the products whose use causes the problem (fertilizers, herbicides, pesticides) and the manner in which they are manufactured and applied.

Another slightly different example of an attenuated cause is land deposition of airborne contaminants, which are then picked up by runoff. Although regulation of air pollution is common, and although there are examples of air pollution controls induced in part by water quality considerations (e.g. regulation of sulphur dioxide to reduce acidification of lakes), most air pollution standards are based on ambient air quality or technology-based approaches. It is still rare for air pollution controls to be based on non-point source water pollution considerations, leaving this an often unaddressed dimension of the non-point source problem.

Although there have been some successes in regulating products that have significant non-point source pollution potential (e.g. banning or restricting phosphates in detergents, or phasing out certain pesticides), most pollution control efforts to date have focused on controlling and treating discharges rather than on product redesign. Reaching far back in the life cycle of products to influence their design or composition as a means of ultimately

influencing the waste streams the products generate is often beyond the scope of pollution control. Nonetheless, the failure to address such attenuated root causes of non-point pollution puts enormous pressure on storm water collection and treatment which, as noted, is a major challenge.

Third, the management of non-point pollution is closely related to land management and land use planning. Decisions regarding what types of activities should occur within given land use areas (such as where and how buildings and roads are constructed) have important effects on non-point source discharge patterns. Unfortunately, non-point source implications are rarely factored into land use planning and management.

Fourth, water scarcity and inefficient irrigation activities greatly affect non-point source pollution. For example, in arid areas where rainwater does not carry residues deep into the soil, excessive irrigation can concentrate pesticides, nutrients, disease-carrying micro-organisms and salts in the top layer of soil, where they pose a greater risk of reaching water systems via erosion and runoff. The failure to address irrigation-related water quality issues as part of the overall strategy for non-point source pollution can be a significant gap in programme coverage.

In sum, there are a number of difficult barriers to constructing an effective non-point source pollution control programme. Yet, given the enormous impact of non-point source pollution on water quality, all these challenges must be confronted and overcome. An effective approach to non-point source pollution requires integrated efforts across a broad spectrum of sectors and stakeholders and on a number of different planes. Legal and policy reform is often necessary to optimize such integration.

3.4.4. Needed policy and legal reforms

Integrated water resource management (IWRM). Non-point source pollution is a challenge that often surpasses the capacity of governments to address and thus calls for other innovative strategies. IWRM is a starting place for overcoming non-point source pollution, as it uses an inter-disciplinary analytical framework that, among other things, considers the linkages between water as a degradable natural resource and the socio-economic value of water. IWRM has great potential as a rationalizing and harmonizing force in water management and planning, particularly in view of its goal of considering the full range of stakeholders relative to a water resource,

including dischargers (both point and non-point), water users and land use planners. The key types of integration essential for non-point pollution control are described below.

- *watershed integration*

Just as in the point source context, an effective approach to non-point source pollution requires that water quality problems be examined through a wide-angle lens that considers both the totality of discharges to a watershed and the relative impacts of all contributory discharges. Discrete and targeted interventions that are not part of a broader watershed strategy may have positive localized results but often fail to produce sustained gains simply because watersheds are themselves integrated ecological systems. As such, degradation in any part of the system has unavoidable implications for the entire system. The preparation of basin-level inventories of pollutants – and of the sources of those pollutants – can be key to an effective integrated approach.

- *pollution integration*

Because most types of pollution eventually become water pollution, a truly integrated approach will need to consider pollution that is not “water pollution” *per se*. Airborne contamination that is ultimately deposited on water, or on land subject to runoff, are examples of these. In view of such pollution synergies, it is vital to develop an integrated policy which, rather than treating land, air and water separately, instead considers all pollution that, irrespective of its starting point, may affect water quality in a given watershed.

- *planning integration*

To regulate water resources comprehensively, land use planning and land management need to anticipate and address water quality impacts associated with development activity. For example, an effective tool for the control of non-point pollution is the creation of buffer zones, i.e. the delineation of areas in which activities that might cause pollution are either precluded or at least strictly regulated and monitored. Geographic concentration of certain kinds of activities through zoning or other land use restrictions can allow for efficiency in discharge collection and treatment, as in the case of sewage treatment plants.

- *social integration*

A key tool for the reduction of non-point pollution is public education and awareness. The behaviour of every individual in society has water quality implications, and the potential for achieving water quality improvements by changing social attitudes and behaviours should not be underestimated. If public education cultivates a societal ethic that favours environmental stewardship and protection, it may greatly influence and improve consumer choices, public consumption and public waste production patterns.

The involvement of citizens and local institutions in water management and pollution control is also vital. Education and awareness-raising strategies can help to foster a shift from a purely top-down approach run by national governments to the development of basin-level authorities active in the creation and implementation of pollution control policies specific to the peculiarities of each basin.

Best management practice (BMP). Increasingly, BMP reference points are available for particular forms of non-point source pollution and should be harnessed. For example, in the irrigation context, farmers can both improve water use efficiency and reduce irrigation-related pollution by calibrating water consumption to actual crop-related water demands (Verona *et al.*, 2000). Similarly, integrated pest management techniques can be used to reduce farmers' reliance on chemical pesticides (Verona *et al.*, 2000). Another example is animal farming and aquaculture: discharges from such facilities can be limited by collecting, storing and treating wastewater and runoff prior to their discharge into receiving waters (Verona *et al.*, 2000).

Effective standard setting. The establishment of effluent limits based on BAT and water quality considerations and the use of BEP should form part of an integrated approach to the prevention, control and reduction of non-point source pollution (Helmer and Hespanhol, 1997). Such limitations and required practices must be expressed in clear terms and given the force of law through legal and regulatory instruments.

Product and process life cycle consideration. Control of non-point source pollution depends to some degree on consideration of the life cycle of products and activities that predictably come in contact with fresh water systems. Examples in this regard include pesticides, herbicides and fertilizers that are carried into waterways by storm water runoff; products that, by virtue of

solid waste disposal practices, commonly wash into waterways; and airborne by-products that ultimately return to earth and wash into water sources. Many of these products and by-products are already subject to regulation for other reasons. Injecting water quality considerations into these existing regulatory practices can offer substantial benefits.

IV. CONCLUSION

Policy reforms should address the twin sources of water quality problems: direct, point source discharges and indirect, non-point source contributors of pollution to the water body at issue. Moreover, policies must consider not only the specific water body but rather all water bodies that share a common watershed or basin. Indeed, the lens should be broader still, approaching the issue of water quality in the context of IWRM, considering water as both a natural resource and a social and economic good. It is only when the water pollution problem is examined from this broader, integrating perspective that sources of pollution can be effectively understood and appropriately controlled.

Further advances in point source and non-point source pollution control will depend on this type of integration as well as on improvements in government oversight. This will require sound decision-making by governments in the establishment of effluent standards and effluent limits, and a commitment to ensure that these standards and limits are enacted and enforced. Without integration and oversight, and without widespread stakeholder commitment to protecting and restoring water resources, effective pollution control is not possible.

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DRINKING WATER**Contents*

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Ensuring access to safe, clean drinking water is one of the principal challenges of water management and a major concern in the developing world. Lack of access to potable water is associated with a substantial burden of death and disease every year. The Millennium Development Goals (MDGs) set the target of reducing by half the proportion of people without sustainable access to safe drinking water, placing the issue squarely on the international agenda.

This chapter explores the political, financial, institutional and technical challenges to the provision of safe drinking water. It then examines policy and regulatory means to increase access to water and to improve its safety. The goal is the formulation and implementation of policies and legislation that ensure the greatest benefit to the most people from available resources. The chapter concludes with a detailed discussion of legislative and regulatory options for drinking water quality standards and laws, drawing on the guidelines of the World Health Organization.

I. DRINKING WATER CHALLENGES

1.1. Political challenges

In the regulation of the drinking water supply sector, the overall objective is to guarantee a supply of water that is safe, reliable and easily accessible (i.e. close to the home and available in workplaces and schools and in public places). Achieving this goal can increase economic and social opportunities for households and for developing countries as a whole. Maintaining its achievement underpins health and economy. Thus, economic development is tied to development of the water supply sector.

All countries face political challenges of one form or another in achieving or maintaining access to safe drinking water. These may come from the profit motive and power imbalances between those that need water and those that have the ability to provide it, for example.

One barrier to ensuring access to water supply is the users' lack of political influence or power. The most powerless are often poor, living in rural and remote areas. Some countries, such as Brazil, have had problems expanding supplies to these disadvantaged groups (UN, 2004b). Political patronage, ethnic bias and religious affiliation may also influence resource allocation, and there is often a tendency to give greater attention to improving services

for those already supplied, especially in urban areas, and to give less attention to the rural and urban poor.

A failure to convince decision-makers of the value of extending the social, health and economic benefits of access to safe drinking water can also lead to a lack of political support. In fact, recent reports from Latin America and other developing regions suggest that a lack of political will, coupled with rapid population growth, is primarily responsible for slow progress toward the MDGs (UN, 2004b).

At times, complacency and political indifference in both developed and developing countries can be shaken by crises such as droughts, floods or outbreaks of disease. Such crises often mobilize public demands for political action, providing opportunistic triggers for rapid progress. Such opportunities should be grasped when they arise, but it is ineffective and undesirable simply to wait for such disasters to occur. It is far better to maintain existing services and implement consistent policies and practices toward extending improved access to safe drinking water and sanitation.

1.2. Financial challenges

Financial challenges to ensuring access to drinking water come in two principal forms: the financing of water interventions (typically borne by central or local government) and the ability – or lack thereof – of the poor to pay for water through regular tariff payments. Poor people often pay more for water in absolute terms than wealthy people, yet the latter receive better and more reliable supplies. Poor people pay more because their households often lack access to public water supplies. As discussed in Chapter 1, this means they must buy more expensive water from vendors and other service providers. In rural areas the “cost” may also take the form of time invested in collecting water – especially by women – squeezing out opportunities for other productive activities such as education or employment.

The costs of establishing an initial connection to piped water systems and the tariff systems that require scheduled regular payments exacerbate the burden on the poor. Regular payments may be inconsistent with the earning patterns of the poor, whose incomes may be highly variable and unstable and whose ability to save is limited. To help the poor gain access to expanded services, countries may need to implement financial reforms, including cross-subsidies, flexible payment systems or development assistance. Water utilities, especially in poor countries or poor regions, often struggle to

generate sufficient cash flows, hence little funding is available for maintenance or expansion. In Lusaka, Zambia, a prolonged lack of investment led to a breakdown in service provision and an inability to extend services to new settlements (WHO, 2003). Towns and communities in developing countries also tend to have limited access to external financing or funding.

In many countries, existing piped facilities are old and need repair. These facilities leak water and, without maintenance, the costs of supplying water increase whilst the value of the supply system decreases. Water that is lost through leakage and poor metering represents a staggering burden, especially in developing countries. The average rate of lost water has been estimated at 37 to 41 percent in the developing world, with regional rates varying from 17 to 62 percent (Lee and Schwab, 2005). In Nairobi and Mombasa, Kenya, water loss was estimated at 50 percent and 40 percent, respectively (Gulyani *et al.*, 2005).

On the basis of limited data, losses in developed countries are believed to be typically closer to 20 percent or less but vary widely, reaching as little as 5 percent in some cases. The volumes can still be substantial. In 2000, licensed water suppliers in England and Wales reportedly lost 3 000 ML per day, representing nearly half the flow of the River Thames in London (NAO, 2000).

1.3. Institutional challenges

Institutional challenges to ensuring access to drinking water and sanitation include the absence of appropriate agencies charged with overseeing and managing water resources and supplies; poor coordination amongst existing agencies; inadequate capacity; lack of accountability; and a lack of appropriate regulatory structures. Institutional reform in some areas will be required to increase access to safe drinking water and sanitation (UN Millennium Project, 2005).

Governments have a range of institutional and management options to ensure provision of adequate services to all. These vary nationally and locally but generally implicate health, environment and drinking water supply agencies (see Table 7.1). Coordination, with involvement of all relevant sectors, is desirable for effective action in increasing access to drinking water supplies. Public health professionals should be involved from the outset

(Bartram *et al.*, 2005). The health sector needs to be involved in setting policy and elaborating legislation as well as identifying investment priorities.

Traditionally, utilities have delivered water services in a top-down approach through public sector monopolies. Government provision has been criticized because it can be perceived as politicized, bureaucratic, inefficient and isolated from public concerns. Over the past 20 years, two alternative approaches to delivery and coverage have been discussed and debated widely. The first is private sector involvement; the second is increased community management. In all cases, any institutional approaches towards water supply management should be accompanied by an adequate regulatory regime and government oversight.

Table 7.1 - Typical Agencies and Authorities with Responsibilities Associated with Drinking Water Supply

Function	Agencies and Authorities
Abstraction licensing	water resource agency, agriculture agency, dedicated abstraction licensing body, river basin authorities, navigation boards, hydroelectricity generators, water supply agency
Water resource quality	water resource agency, environment protection agency, river basin authorities, health agency, water supply agency, local governments
Drinking water supply service quality	water supply regulator, consumer protection bodies, water supply agencies, health agency, local government
Ancillary services (e.g. plumbing)	professional associations, trade associations, water supply agency
Public health protection	health agency, local government, water supply agency
Licensing of materials and chemicals	certification agency, licensing authority, standards association, health agency, water supply agency

Source: Adapted from Howard and Bartram, 2003b.

1.3.1. Private sector involvement

Private sector involvement in the supply of drinking water and sanitation services can range from privatization of water supply (including associated asset management); through various forms of licensing; to sub-contracting specific tasks or roles to private sector entities. This last is almost universal, and most discussion of private sector participation in fact focuses on various forms of licensing to subcontract specific tasks or roles to private sector entities. In addition to the simple provision of goods and services, the major forms of private sector participation include:

Subcontracting. The government-owned utility subcontracts with private companies to carry out specific activities such as meter reading, billing and payment collection. Private sector involvement is limited, and subcontracting arrangements are unlikely to stimulate private investment. The government utility retains a high degree of administration and oversight.

Management contract. With a management contract, a private company operates water and sewerage services for a fixed term (e.g. five years), for which it is paid a fee. Management contracts are an extension of subcontracting for services but, as with subcontracting, they provide few incentives for private sector investment. Management contracts only apply to established infrastructure and the government utility retains significant administrative duties as well as responsibility for investments.

Lease (“affermage”) contract. With this type of contract, the private sector is engaged for extended periods and accepts broad responsibilities for operation and performance. A private company leases the water supply and sewerage assets for a period of 10 to 15 years and operates them in return for the right to revenues from the customers. The main advantages of this approach are that the private operator has clear performance incentives and has necessary working capital. However, the arrangement remains administratively demanding for the public sector, which also remains responsible for investments.

Concession contract. With a concession contract, the private sector operates and maintains existing facilities and is also responsible for new investments. These contracts are generally longer than affermage contracts (typically 25 to 30 years), which may increase external investment. It also transfers some

financial risk to private operators. The best-known examples of this approach are in France (Ballance and Taylor, 2005).

Build-operate-transfer (BOT) contract. Under a BOT contract, the private sector is given a contract to build and operate bulk facilities. This form of private sector participation enables government utilities to divest involvement in major infrastructure construction. Potentially, it can increase private financing for construction and delivery of bulk services and it can transfer financial risks to private companies. However, it has been suggested that, because of reduced oversight, BOT contracts present a risk of substandard distribution systems, operations and performance.

Asset sale. This is the most complete form of private sector involvement, where government sells the company and the infrastructure to the private sector. The best-known example of this approach has occurred in England and Wales. Public perception of asset sales can be very negative and can raise substantial political problems (Briscoe, 1997).

In all these arrangements, government supervision of the private actors is essential to ensure that their commitments are fulfilled and that the quality of service and public health are protected. For example, in England and Wales, licences to supply water can be withdrawn by the government if required levels of service are not maintained. In developing countries, however, the institutional capacity to monitor, evaluate and regulate the private sector is often lacking, resulting in poor provision and service.

Evidence indicates that after a surge of interest in the early 1990s, international private investment peaked in 1997, declined to a low in 2002 and has subsequently slowly regained ground (World Bank, 2009a). Private operators supply water only to an estimated three percent of the population in developing countries (OECD, 2003). These low levels of private participation may be due in part to a focus on persuading international private companies to become involved in supply in developing countries rather than supporting and strengthening indigenous private sectors that may be better placed to deliver sustainable services. On the other hand, there are significant barriers to private investment in drinking water supply, particularly in developing regions. These can include low profits, high initial capital costs, extended periods required to achieve financial return, political difficulties in establishing cost recovery and economic and political instability.

Supporters claim that private sector involvement provides opportunities for improved efficiency and better management, and therefore improved access to water. They also argue that it may provide greater private investment funds, creating opportunities to finance new infrastructure that already over-extended government budgets otherwise could not. By contrast, critics suggest that private sector involvement in water supply commercializes a public good and diminishes government involvement in what many see as the provision of a basic necessity, and argue that the claimed efficiencies of private sector participation have not been realized in practice (see e.g. Sierra Club, 2003; Wolff and Hallstein, 2005).

Because drinking water supply is perceived as a basic service essential to health and well-being, the public may expect water to be provided at low or nominal cost, at least to the disadvantaged in order that they be able to afford it. However, to ensure a sufficient rate of return for private investment, water charges (which may have been held at artificially low levels for decades) are usually raised. But marked increases in charges to achieve cost recovery are unpopular and can be politically harmful. An alternative is one that South Africa chose: setting a standard price for a minimum volume and increasing charges in proportion to increased use. This ensures low-cost provision for basic needs. Some jurisdictions have also established independent economic regulators to set fair prices to protect both the private sector investor and the public.

Another fear of private sector involvement is that suppliers may disconnect users as a penalty for non-payment. Amongst other things, this could have implications for health, may impinge on the human right to water (see Chapter 10) and would disproportionately affect the poor. Responses such as reducing flows to provide minimum volumes should be considered for non-payment problems.

Efforts at privatizing municipal water supply in developed and developing countries have been accompanied by strong public opposition. Especially controversial is participation of private interests in policy-making and decision-making. Even the idea that the private sector – meaning companies or other non-governmental associations or corporations – would participate at all in drinking water and sanitation supply decisions has created controversy.

1.3.2. Community management

Direct management of water supplies by communities or local institutions is common in both developed and developing countries and can cover both piped distribution systems and non-piped sources. Supporters of community management suggest that community empowerment, engagement and capacity building are vital to expanding access to improved drinking water supplies. Moreover, management of water and sanitation services at the lowest appropriate level has been identified as a critical action in meeting the MDG targets (UN Millennium Project, 2005).

On the other hand, community management has been criticized because of evidence of low sustainability (high failure or non-functioning rates in infrastructure). It often relies on untrained and sometimes unpaid community members. Some of the perceived weaknesses of community management include:

- lack of commitment to maintaining the water supply and a lack of a feeling of ownership of the supply;
- financial constraints in meeting recurrent costs;
- an inability to demonstrate improvements in water quality and benefits such as improved health;
- community-level committees and local operators lose interest or move away;
- lack of “backstopping” service, such as technical or managerial support.

Community management is unlikely to offer more than an interim solution to system management (Carter *et al.*, 1993). Work has highlighted two key project factors associated with improved sustainability of community management systems: periodic external support to water committees for management issues (e.g. tariff setting and bookkeeping) and technical training workshops for water system operators (Davis *et al.*, 2008).

If community management is to function effectively, the local authority or community must have the authority, financial resources and capacity to deliver the required level of service (UN Millennium Project, 2005). The supporting governmental or non-governmental agency needs to maintain ongoing technical and managerial support. Ownership and responsibilities related to management and operation of community supplies need to be clearly identified, delineated and accepted.

Finally, an appropriate balance must be established between central oversight and local institutions and communities. The central government should be responsible for setting standards and for surveillance and monitoring of community-managed supplies. Regulatory oversight should accompany backstopping support (i.e. such as training and capacity development). In this way, combined systems of community management and government monitoring can be effective (Howard, 2002).

1.4. Technical challenges

In addition to political, financial and institutional concerns, technical constraints can make it difficult to ensure reliable access to safe drinking water. This is true especially in rural communities, as they are widely dispersed and thus present logistical problems associated with installation, management, maintenance and surveillance of drinking water supplies; and in dense urban slums. Wide dispersal may also result in poor communication between centralized agencies in urban centres and local agencies and communities.

Infrastructure developments need to take into account the technical abilities of rural communities. Practical and workable solutions are paramount. There is little point in installing facilities that are beyond the capacity of responsible agencies or communities to maintain. Legislation should take into account the technical capabilities to facilitate implementation.

II. LEGISLATING ACCESS TO SAFE DRINKING WATER

2.1. Drinking water legislation

To address the preceding challenges, a comprehensive legal framework for drinking water can help ensure both progress toward universal access to safe drinking water and a progressive increase in service quality and water safety. The nature of drinking water legislation will vary from country to country and even within countries. It will be shaped by the legal system, the constitutional framework, institutional and legislative arrangements and existing political and regulatory approaches. Because of the complexity of the regulatory framework and the human health issues involved, drinking water is often addressed in separate legislation from that on water resources or the environment.

The content of the legislation will also vary (Howard and Bartram, 2003b). There are, however, some basic issues that must be addressed. Amongst others, these include assignment of authority to responsible agencies, definition of duties of water suppliers, setting of water charges, protection of water sources and enforcement of drinking water quality standards. Ideally, drinking water legislation should also address the political, financial, institutional and technical challenges reviewed above. Legislation should at a minimum aim at ensuring continuity of service, physical accessibility and initially expansion of (rather than improvements to) water service provision. These and other elements of drinking water legislation will be discussed below.

Laws adopted by legislatures tend to be relatively static and can be changed only through an extended process of amendment. Therefore, only the essential provisions should be delineated within the law, leaving the more detailed and technical components for elaboration in regulations, standards, guidelines and codes of practice (FAO, 2005). Water quality standards, for example, may be periodically reviewed and frequently change in a dynamic process (Ince and Howard, 1999).

2.1.1. Basic elements

Assignment of responsibility. A key factor affecting water service performance is whether legislation effectively assigns responsibility to implement and coordinate activities (Kandiah, 1995). To ensure performance, legislation should designate the agencies that will be responsible for ensuring the quality of drinking water supply services. The legislation should clearly delineate their roles and responsibilities in implementing supply and sanitary services and allowing them to operate properly (Smets, 2006).

In particular, legislation should differentiate between who is responsible for providing water supply services and who is charged with compliance monitoring. For example, service quality may be controlled by the supplying agency and independently monitored by a separate agency. Governments may also choose to control or monitor water services through external auditors. Whatever the set-up, it is advisable to establish mechanisms for ensuring that activities and functions are coordinated. This could be through legislation or through memoranda of agreement between involved agencies. Legislation may also decentralize responsibilities, for example to regional or local governments. In the European Union, for example, the responsibility

for water service control is in the hands of local governments, not at the Commission or even national level (Smets, 2006).

Water suppliers. Legislation will have to regulate the entities that supply water, which range from large urban suppliers to community-managed suppliers, from independent utilities to local government-run water services to private sector entities. The legislation may establish a licensing scheme, whereby suppliers must apply for a licence (meeting certain prerequisites and agreeing to follow certain conditions), subject to oversight and enforcement by the government.

Legislative provisions should outline the responsibilities of suppliers both in times of normal operation and during emergencies. For example, legislation may provide performance indicators within licence conditions, such as requirements for water quantity, water pressure and consumption; efficiency of supply including controls on leakage; continuity of supply including specifications relating to service interruption (length of time and frequency); coverage and accessibility including requirements relating to extension of supply; and minimum service standards for how to deal with customer complaints and response times.

Legislation may also impose certain limitations on the scope for the private sector to acquire or manage water supplies. It may also set conditions for when water supply services move from the public to the private sphere and vice versa (Smets, 2006). Some countries, including Belgium, the Netherlands and Uruguay, have imposed conditions to prevent privatization of the water supply altogether.

Water pricing. Only a few countries today provide water for free (e.g. Ireland); most charge for the provision. Where water is free or subsidized, the costs of supply are typically borne through taxation. More frequently, legislation implements flat rate tariffs, social tariffs or progressive (consumption-based) tariffs.

Flat rate tariffs take into account the household size, the location of the home or property, the property value and the number of faucets in the home (Smets, 2006). Thus, a family living in a large home in a wealthy neighbourhood pays a higher rate than a family living in a small home in a poor neighbourhood. Legislation may also set up a social tariff, which varies depending on additional factors such as the composition of the family and their income, as well as the amount of water they consume (Smets, 2006).

Some countries (e.g. Mali) have included in their social tariffs reduced rates for whole categories of people.

Progressive tariffs start at a certain price for a minimum amount and increase with the amount of consumption. Progressive tariffs are common and can be found in the legislation of Argentina, Belgium, India, Italy, Uruguay and some locations in the United States. A progressive tariff can also be combined with a quota system, whereby the legislation establishes a free, minimum amount, whilst every unit of water used over that amount incurs a charge (e.g. Colombia, South Africa) (Smets, 2006).

Monitoring and reporting. Legislation should require periodic reporting to regulatory agencies, including health agencies. This should be a requirement whether water supplies are operated by government or by the private sector. Monitoring and surveillance are particularly important for rural populations in developing countries, who receive water through diverse means of supply and infrastructure, many of which have a high failure rate.

Reporting to consumers should also be required. Legislation should ensure that the public at large may obtain (or shall be provided with) information about the water supply, such as the number of households served, the quality of the water, the continuity of services and the tariffs set. An additional provision may require financial reporting on the water services. This may include stating the types of funds the suppliers are receiving and from what sources, the tariff structures and the actual cost of provision.

Public participation. The legislation may address public participation in water supply provision. For example, users may be called upon to provide comments on proposed regulations or agency actions. In most developed countries, the introduction of new standards relating to drinking water quality and treatment requires extensive public consultation before adoption. In developing countries, a standards agency, rather than the regulatory body, often sets standards and consultation may be limited – for example to an expert group. Legislation may also require that the public be represented on government and private-service supplier commissions. For example, France and New Zealand have legislated to allow users of water services to participate in certain management and administrative decisions (Smets, 2006)

Finally, legislation should provide remedies for members of the public who claim violations or infringements of their access to water or service quality.

This might include remedies for improper cut-offs, over-charging or poor water quality.

Protection of water sources. Many activities affect water quality, such as agriculture, mining, forestry and human settlements. The goal of legislation and regulation in this area is to minimize adverse impacts by protecting water sources, thus preserving drinking water quality.

Most often, the protection of water sources is regulated through environmental laws which are enforced by the environmental protection agency in conjunction with agriculture- and industry-related agencies. Legal provisions may set up protection zones around water sources and establish mechanisms to prevent access to surface water sources. Other legislation, such as land laws, may establish restrictions on land use near water sources. Water resources laws generally establish systems to license and monitor water abstractions (see Chapter 5) and to regulate pollution discharges (see Chapter 6).

Drinking water quality standards. Drinking water should be safe to drink. Thus, legislation should identify responsibilities for assessing systems, ensure their management so as to guarantee delivery of safe water, set standards and establish mechanisms identifying and acting on deviations from those standards. Monitoring requirements, responsibilities and actions in the event of non-compliance with standards should also be identified.

2.1.2. Measures to ensure access

Prioritizing drinking water. Wherever the drinking water provisions are located, a statement of purpose and intent concerning protection and support of public health through provision of safe drinking water to the general population will underscore the importance of universal safe water supply. Many countries prioritize water uses within their legislation, and governments will normally want to ensure that the highest quality resources are set aside for drinking water. In times of drought or water scarcity, governments may have to curtail certain uses. Legislation should clearly state that other uses will be prohibited or limited before any restrictions can be placed on essential domestic uses (e.g. drinking, cooking and hygiene).

Ensuring continuous supply. In many countries, if a user does not pay his or her water bill, the supplier is permitted to cut off the water supply to the home (or

business). These cut-offs can have disastrous effects on human health and hygiene, and they run counter to a country's efforts at ensuring access to all.

To ensure a continuous supply of water, legislation can limit cut-offs or institute alternatives. Where cut-offs are permitted, laws should specifically designate which individuals or organizations cannot be cut off from water supplies (Smets, 2006). Legislation may also identify the types of cut-offs that *are* permitted, if any, such as to second homes and uninhabited homes. In these cases the risks to human health are lower. Because protection of human health is ultimately a government responsibility, it alone (not the companies or non-governmental organizations involved in distributing water) should determine which users are the most vulnerable (Smets, 2006). This is because water distributors, as a general rule, are likely to have the financial interest of the business or service foremost in mind rather than guaranteeing universal access even to those who cannot pay.

Governments may also adopt alternatives to ensuring a continuous supply of water. For example, legislation may prohibit complete water cut-offs but allow water distributors to limit supply to sufficient minimum levels. Governments could also cover the costs of water supply to the poor, or could require the construction of public fountains where people could obtain their water requirements (Smets, 2006).

Ensuring a continuous supply is an especial challenge during emergencies. For example, if there is a flood or drought and the water infrastructure is out of service, water may be provided through tanker trucks, bottled water deliveries or other alternatives. Legislation should specify whether government, utilities or users will cover the cost of such supplies. Poor users may be disproportionately affected by additional costs.

Guaranteeing physical accessibility. Availability means more than a continuous flow of water. To be available for use by all, water supplies need to be physically accessible within a short distance from the home. One way to ensure physical accessibility is to increase the number of water access points, especially for land occupiers (such as those in shantytowns) who may be residing on property without legal deeds (Smets, 2006). Governments could increase supply points by encouraging construction of public street fountains, allowing access to fire hydrants and "water kiosks" or providing water through tanker trucks.

Expanding rather than improving service. Financing is often an issue when dealing with the expansion of water supplies. To ensure that everyone has access to the necessary minimum amount of water, legislation should state that supplies should be expanded to those without present access before existing supplies are improved.

2.1.3. Bottled water

Bottled water is typically high in cost and is not considered a reliable supply of safe water for domestic purposes since volumes purchased are typically limited to consumption or part of the consumption requirement only. Nevertheless it is seen as an important source of “safe” water by some population groups and at certain times (during travel, for example).

Bottled water is typically regulated as a foodstuff and the corresponding requirements are found in food-related rather than water supply service-related legislation. This can lead to inconsistencies. The Codex Alimentarius Commission of WHO and FAO (Codex) has established a recommended code of hygiene for the safe manufacture and distribution of bottled waters and two standards for the quality of bottled water – one for mineral waters and the other for non-mineral waters. These cover the range of commercial packaged water by setting quality standards to be followed by producers and resellers. They describe the product’s characteristics and its composition, including limits for certain chemicals, as well as hygiene, packaging and labelling requirements.

The reason for the distinction between natural and treated water is because of the important value that certain cultures place on the perceived “healthy” properties of some high mineral content “natural” waters. The Codex standard for waters other than mineral waters is generally aligned with the recommendations of WHO guidelines (2008). The Codex standard for mineral waters permits concentrations of some substances to exceed concentrations considered by WHO to be suitable for life-long consumption. In the developing world, a rushed implementation of Codex standards for packaged waters for international trade in order to access foreign markets may lead to distortions internally – by diverting resources from control of the safety of drinking water supply to the control of bottled/package water.

2.2. Framework for safe drinking water

The goal of drinking water legislation is to guarantee access to safe drinking water. “Safe” drinking water means water that does not represent a risk to health over a lifetime of consumption. To ensure that water is safe, legislatures and agencies must set standards for water quality and make sure that these are monitored and enforced.

The World Health Organization (WHO) developed its Guidelines for Drinking-water Quality (2008) to help countries establish standards for drinking water safety. The guidelines outline a preventive, risk-management approach to ensuring that drinking water supplies are safe. The framework is based on meeting defined health-based targets. These targets can be met by implementing a management plan that incorporates control measures to prevent human exposure to microbial and chemical hazards. The framework also incorporates a requirement for independent surveillance to ensure that the management plans operate effectively.

The guidelines represent a consensus around evidence from accepted best practice and sound science. They represent the scientific point of departure for national authorities developing drinking water standards and regulations based on prevailing environmental, social, economic and cultural conditions. The approaches adopted by national authorities vary. Some have used the guidelines as supporting information or a scientific starting point in developing national guidelines or standards whilst others have adopted the WHO guidelines as *de facto* standards. Jurisdictions may have mandatory standards (e.g. United States of America, European Union) or establish non-binding guidelines (e.g. Australia, Canada).

The process of setting water standards needs to be transparent, and the negotiations between regulators, suppliers and the public need to take into account social demands for protection of public health and public perception of risk. Priorities should be established after identifying key parameters, setting appropriate standards for the parameters and ensuring that compliance will be monitored. Because the WHO guidelines list nearly 200 chemicals, some of which may not be universally relevant, countries must assess their local conditions and select the most appropriate standards for their circumstances.

Water quality standards usually include levels or limits of pollutants or microbial and chemical agents that are allowed per unit of water depending

on the use of that water. Adoption of less stringent interim standards may encourage progressive improvement of water safety. Interim standards include introducing chlorination immediately followed by progressive increases in water treatment or setting an initial target for a chemical such as arsenic as a first step to minimize significant health risks (AusAid, 2005). Interim standards may be appropriate where water quality problems require significant upgrading of water infrastructure that will take an extended period of time or require large-scale investment.

Relaxations or exemptions are useful for parameters of lesser health concern. This could take the form of allowing a percentage of samples to exceed a standard. The relaxation or exemption could be time-limited and linked to an agreed and defined programme of action to address water-borne hazards.

2.2.1. Health hazards

Microbial hazards, pathogenic bacteria, viruses, protozoa and helminths that cause infectious disease represent the greatest concern for public health. Many of these pathogens in water come from human or animal excreta (faeces). Some of the organisms such as *Legionella* and mycobacteria grow in piped water distribution systems, whereas others such as *Dracunculus medinensis* (guinea worm) occur in source waters. These pathogens are transmitted primarily through ingestion of contaminated drinking water, but illness can also be caused by inhalation of contaminated water (e.g. *Legionella*, *Naegleria fowleri*) or by contact (e.g. *Schistosoma*, *Burkholderia pseudomallei*). For diseases such as schistosomiasis, the availability of safe drinking water reduces contact with contaminated sources and thus helps prevent disease. Table 7.2 sets out microbial hazards that can be water-borne.

Drinking water guidelines and standards have traditionally defined microbial quality based on bacterial indicators of faecal contamination (thermotolerant or faecal coliforms and *E. coli*), the premise being that the major risk to human health is the presence of faecally-borne organisms. These bacterial indicators have significantly contributed to the assessment of water quality and the protection of public health.

These indicators are not perfect, however. Although the use of faecal indicators has been important in promoting water safety, indicators are less directly associated with non-bacterial pathogens. Some viruses and protozoa may survive for longer periods in drinking water than the bacterial indicators and may therefore be present in the latter's absence. Disease outbreaks have

arisen from drinking water without indicator organisms being detected (Craun *et al.*, 1997).

These limitations and others have shifted attention to broader indicators of contamination, indicators of effective removal processes and evidence of implementation of preventive measures. Protecting water sources from human and livestock waste minimizes the presence of faecal contamination.

The level of groundwater protection can be assessed by sanitary inspection of wellheads to ensure that structures and seals are intact, protection zones are maintained and barriers to prevent surface water seepage are in place (Howard and Schmoll, 2006). Finally, to measure treatment success, disinfectant concentrations indicate the removal of bacterial and viral pathogens, whilst turbidity indicates effectiveness of filtering viral and protozoan pathogens (WHO, 2008; LeChevallier and Au, 2004).

2.2.2. Chemical hazards

The WHO Guidelines for Drinking-water Quality address a broad range of chemical hazards, including naturally occurring inorganic chemicals; industrial chemicals; agricultural chemicals; water treatment chemicals and infrastructure materials; pesticides used in water to protect public health (e.g. larvicides); and cyanobacterial toxins. Few chemicals in drinking water have been clearly associated with large-scale health effects, although two notable exceptions are naturally occurring fluoride and arsenic (WHO, 2008).

The principal focus for setting guideline values and standards for chemicals has been to identify concentrations that are considered to represent “safe” levels. Chemical standards are set based on whether they have a “threshold” or “non-threshold” effect. The threshold is the level above which a chemical may cause an adverse effect and, conversely, below which no adverse effect occurs.

For chemicals that have a threshold effect, the guideline’s numerical values are based on concentrations of the chemical that will have no adverse effect over a lifetime of exposure. By contrast, non-threshold chemicals are harmful at any level; hence there is no threshold level at which an adverse effect can be avoided. Non-threshold chemicals are largely genotoxic carcinogens (cancer-causing agents). Numerical standards for these chemicals are based on concentrations that represent a perceived tolerable risk (10-5 excess risk of cancer from lifetime exposure) (WHO, 2008).

Table 7.2 - Water-Borne Microbial Hazards

Pathogen	Infectivity	Primary Source	Route of Infection
Bacteria			
<i>Burkholderia pseudomallei</i>	Low	Natural	Contact
<i>Campylobacter</i>	Low	Faecal	Ingestion
<i>Escherichia coli</i> pathogenic	Low	Faecal	Ingestion
<i>E. coli</i> enterohaemorrhagic	High	Faecal	Ingestion
<i>Legionella</i>	Low	Natural	Inhalation
Mycobacteria (non-tuberculous)	Low	Natural	Inhalation/contact
<i>Pseudomonas aeruginosa</i>	Low	Natural	Contact
<i>Salmonella typhi</i>	Low	Faecal	Ingestion
Other salmonellae	Low	Faecal	Ingestion
<i>Shigella</i>	Moderate	Faecal	Ingestion
<i>Vibrio cholerae</i> – toxigenic	Low	Faecal	Ingestion
Viruses			
Adenoviruses	High	Faecal	Ingestion/respiratory
Enteroviruses	High	Faecal	Ingestion
Hepatitis A	High	Faecal	Ingestion
Hepatitis E	High	Faecal	Ingestion
Noroviruses and Sapoviruses	High	Faecal	Ingestion
Rotaviruses	High	Faecal	Ingestion
Protozoa			
<i>Acanthamoeba</i>	High	Natural	Contact
<i>Cryptosporidium</i>	High	Faecal	Ingestion
Pathogen			
<i>Cyclospora</i>	High	Faecal	Ingestion
<i>Entamoeba histolytica</i>	High	Faecal	Ingestion
<i>Giardia</i>	High	Faecal	Ingestion
<i>Naegleria fowleri</i>	High	Natural	Nasal passages
<i>Toxoplasma gondii</i>	High	Faecal	Ingestion
Helminths			
<i>Dracunculus medinensis</i>	High	<i>Cyclops</i>	Ingestion
<i>Schistosoma</i>	High	Aquatic snails	Contact

Source: WHO, 2008.

2.3. Health-based targets for drinking water quality

Water quality standards are generally based on health-based targets, which define drinking water safety and set the benchmarks for water suppliers, public health officials and the population served. Health-based targets can gradually improve the drinking water supply. The targets should be part of overall national public health policy and should therefore be set by a government. Health-based targets need to be realistic and relevant to local economic, social and cultural conditions and take into account financial, technical and institutional resources. Targets should also consider factors such as existing health burdens, current water quality and accessibility and availability of resources, including user willingness and ability to pay. The judgment of what is considered a tolerable risk is for each country to decide.

In developed countries, the debate about water quality requirements, setting of standards and appropriate levels of risk generally concerns an extensive drinking water infrastructure that has been installed in all but possibly some rural and remote areas. The key financial and technical challenges in these countries often relate to efficient management of existing systems, including rehabilitation, replacement and enhancement strategies in the pursuit of progressively improved drinking water quality. In some cases, attention may be focused on increasing the range of hazards addressed, although some may be of limited health significance. A common theme in developed countries has been a marked increase in the numbers of regulated contaminants. For instance, the number of contaminants regulated by federal drinking water standards in the United States increased from less than 20 to more than 100 between 1963 and 1993 (NRC, 1997).

The circumstances in middle income and poor countries differ because these nations have incomplete water supply infrastructure and higher numbers of people with limited access to drinking water. Thus, to make the best use of resources for the public benefit, these countries must allocate their resources both to expanding supplies and ensuring that safety standards are met. Extending access to improved water sources with low public health risk could be a higher priority than ensuring that stringent standards are met in supplies serving smaller numbers of people. There are ethical and political dimensions to consider when adopting lower water quality requirements, although care must be taken to ensure that debates over such issues are not dominated by well-served elites.

Different types of health-based targets include the following:

Health outcome targets can be established where the burden of disease is measurable and the target is defined as a quantifiable reduction in the level of disease. Health outcome targets are primarily applicable to microbial hazards and chemicals with clearly defined health impacts (e.g. arsenic). Measurement may be through epidemiology studies and surveillance or be based on quantitative risk assessments.

Water quality targets generally take the form of numerical values – for example national standards or guidelines for chemicals.

Performance targets are generally applied to the control of microbial hazards, but can apply to any system where reductions in or prevention of contamination can be measured (through treatment performance or source protection measures). Targets are often based on required removals of pathogen groups or reduction in chemical contamination (e.g. in arsenic or fluoride removal systems) and prevention of recontamination.

Specified technology targets are generally applied to small community supplies and to household-level devices. They can take the form of approved technologies to be used in certain circumstances (e.g. requirements for chlorination), specific control measures such as protection of wellheads and construction standards.

2.3.1. Water safety plans

Health-based targets provide the benchmarks to ensure safe drinking water. These targets are achieved through the design and implementation of preventive risk management plans, which in the WHO guidelines are called water safety plans (WSPs). WSPs and other related risk management approaches are intended to prevent problems before they arise. WSPs also identify potential contamination sources and select and implement appropriate control measures to remove hazards or reduce them to acceptable levels. Moreover, WSPs monitor the control measures to ensure that they remain operational. Traditional end-point monitoring is retained but not used as a primary management tool. Rather it is used to verify that the management systems are correctly designed and implemented and result in the provision of safe drinking water.

WSPs may be applied to all types of systems regardless of size or complexity. Each plan will reflect the nature of the water supply: small systems generally require simple plans, larger systems, more complex ones. General guidance has been developed for the design and implementation of WSPs (Bartram *et al.*, 2009), and formal and informal networks have been established to support implementation of WSPs in large systems, small community supplies and households (WHO, 2009).

Operators of large systems, particularly in developed countries, generally have sufficient resources and the capability to design and implement WSPs, although guidance published by WHO (Bartram *et al.*, 2009; WHO, 2005a) can still help. Implementation of WSPs is more challenging in developing countries, but emerging experience shows positive results (Howard *et al.*, 2005).

Operators of smaller supplies, including those under community management, will need additional support (Bartram *et al.*, 2009). Small communities, particularly those in rural areas, receive less attention and resources than larger systems, mainly because of community dispersal over large areas; distances of the systems from local, provincial or national governments; lack of communication and coordination; lack of political influence in national agencies; and lack of local resources available for operation and maintenance. Operators of small community systems may have limited training and in the case of community-managed systems, may be untrained or unpaid volunteers, as already noted. Reducing reliance on end-point testing can mitigate some of these disadvantages, since small rural schemes and household systems will find monitoring control measures easier than traditional monitoring. In these circumstances, operational monitoring of management systems can be based on observation or the use of field kits (e.g. for measuring chlorine concentrations).

Small systems, whether in developed or developing countries, tend to have poor levels of maintenance and management as well as frequent functional failures. In the United Kingdom, 47 percent of small systems recorded at least one unsatisfactory result in an assessment of water supplies conducted over a 20-month period (Fewtrell *et al.*, 1998). In the United States, during one 27-month period, 23.5 percent of community water systems violated microbial quality standards on at least one occasion (NRC, 1997). Over 600 water-borne outbreaks have been associated with small supplies in the United States (NRC, 1997) and 25 outbreaks for small supplies in the United Kingdom (Said *et al.*, 2003).

There have been problems in large systems, as well. In the United States city of Milwaukee, contamination of drinking water supplies by the parasite *cryptosporidium parvum* caused over 400 000 people, roughly one-quarter of the city's population, to become ill, and over 100 people died (Corso *et al.*, 2003).

Experience in Bangladesh has shown that WSPs can be implemented in small systems, provided that appropriate support and tools are developed (Mahmud *et al.*, 2007). A number of other countries are developing tools, such as computer-based software as well as written materials, to assist operators or those with oversight of small supplies to implement WSPs (WHO, 2005b). In some cases, generic risk management plans can be developed at central level, with local-level implementation focusing on monitoring and actions to maintain supplies in good sanitary condition (Mahmud *et al.*, 2007).

In addition to developing tools to assist in implementation, capacity building among community supply operators is also needed. Capacity includes education and training for rural communities, mechanisms for providing technical support to local managers of community supplies and measures to increase community support and involvement in the application of WSPs (Bartram *et al.*, 2009).

2.3.2. Household treatment

Around 50 percent of people in developing countries have to transport and store water in the home, thus simple techniques for treating water at home and storing it safely produce large health benefits. Moreover, simple low-cost interventions at the household and community level can dramatically improve the microbial quality of stored water and reduce the attendant risks of diarrhoeal disease and death (Fewtrell *et al.*, 2005; WHO, 2002). Safe storage involves minimizing contamination using storage vessels with narrow openings and using dispensing devices such as taps or spigots.

Although 83 percent of people in developing countries have access to improved drinking water sources, only 42 percent have access through a household connection or a yard tap. The 17 percent with no access to improved water have no choice but to carry water from unsafe sources. Home water treatment and safe storage do not diminish the requirement of access to safe water supplies, but they can be adopted quickly prior to the provision of enhanced infrastructure (WHO, 2002; WHO/UNICEF, 2005).

A range of water treatment technologies have been developed. Examples of technologies that reduce microbial contamination include chlorination, solar disinfection, combined flocculation and chlorination powders and finally, ceramic filtration.

Household water management practices have been introduced in about 50 countries involving treatments ranging from filtration through sari cloth and nylon to commercially produced sachets of flocculants and chlorine (WHO/UNICEF, 2005). A key criterion for management practices is that the materials be locally available and acceptable. In Kenya a solar disinfection project was successful because community members were able to obtain suitable bottles. Also in Kenya, local factories producing ceramic filters reportedly recoup costs within a year of production.

2.3.3. Surveillance

The final component of the framework for safe drinking water is independent surveillance to assess compliance with health-based targets. Broad-based surveillance surveys have been successfully developed in Peru and Uganda (Howard and Bartram, 2005). These surveys include assessment of access to water supplies; use of water sources; water quality; sanitary condition; water quantity; continuity; cost (affordability); and leakage. Both case studies showed that information on these key indicators could be collected in a cost-effective way, which supported management actions that improved water safety. In both cases, the surveillance programmes improved operation and maintenance and household water hygiene. For urban and small community water supplies, surveillance should include approval of WSPs as well as assessment of drinking water quality.

2.3.3.1. Drinking water quality

Surveillance of drinking water quality requires the surveillance agency to audit a water supplier's performance or perform a direct assessment through inspections and independent water quality testing (WHO, 2008). Auditing normally involves reviewing WSPs, examining records to ensure that system management is being performed in accordance with the WSP, checking records to ensure that control measures have operated within prescribed limits and reviewing drinking water test results to check for compliance with specified targets. Audit-based approaches place responsibilities on water suppliers to provide information to the surveillance body, and this requirement needs to be enforceable.

Direct assessment usually includes sanitary inspections of water supply systems (from source to supply to consumers) in addition to drinking water quality tests. For small suppliers, the surveillance agency's direct testing may be the principal source of water quality data. Direct assessment requires technical expertise in sanitary inspections, collecting samples and interpreting results. The surveillance agency will require access to analytical facilities.

Where there are large numbers of community or household systems, frequent direct assessments of all supplies may be impossible. Instead, rolling programmes or well-designed surveys may provide at least overviews of water quality and evidence of general problems. Irrespective of the method of surveillance, the surveillance agency and water providers must communicate and cooperate to maximize the benefits, implement necessary changes and improvements and avoid duplication of effort.

Control of water safety and surveillance of small community supplies present particular difficulties, especially because of the limited capacity of operators to implement management programmes and undertake monitoring. The numbers and dispersal of these systems also raise problems. Surveillance of community-managed supplies is more likely to produce positive outcomes if the emphasis is on providing support to enhance good management. Visits by surveillance agencies may for example include health education and health promotion activities to promote sound management practices. Surveillance can include participatory activities relating to sanitary inspections and testing using field test kits. Where appropriate, visits could also include household storage examinations and stored water tests. Household treatment systems should be surveyed to determine their acceptance, adoption and maintenance.

2.3.3.2. Service level

In addition to assessments of water quality, surveillance should determine levels of service including quantities of water supplied, continuity of supply, accessibility and affordability. The amount of water supplied to households has a significant impact on public health. Estimates of the necessary volumes indicate that basic services require an average of 20 litres per person per day whilst optimal access requires 100 to 200 litres per person per day (Howard and Bartram, 2003a). Assessment of the quantity of water is most effectively carried out using the service level as a proxy, as extensive research has shown that the amount of water households collect is a function of the distance and time taken to collect it (Howard and Bartram, 2003a).

Surveillance should also consider the continuity of supply. Frequent short-term interruptions to supply adversely affect hygiene and lead to increased need for household storage. Short-term interruptions may be caused by restricted pumping regimes, power restrictions or outages, peak demands exceeding system capacity and infrastructure failure (e.g. pump failure, treatment failure, pipe bursts). Climatic conditions and competing uses, such as irrigation, may also cause seasonal water shortages. These longer-term interruptions may require alternative water sources that are inferior in quality or farther away. Surveillance should determine the causes of discontinuity and possible solutions. It should also assess the responsibilities and performance of water suppliers in relation to maintenance and timeliness of repairs. Furthermore, surveillance should identify requirements for infrastructure improvements to reduce interruptions.

Affordability of water affects patterns and volumes of use and the sources of water used. Determinations of affordability should take into account all costs associated with drinking water, including costs of connection to piped water supply and volume tariffs. In addition, any costs of household treatment and storage should be included as well as any costs associated with alternative water supplies, such as those provided by vendors.

2.3.3.3. Surveillance in practice

Evidence indicates that surveillance is under-utilized in developing countries. It also appears that surveillance of piped supplies in urban areas is performed more extensively than in rural areas, but with alternative sources and household water rarely included (Howard and Bartram, 2005).

Surveillance functions and responsibilities will vary according to legal, administrative and technical circumstances at national and local levels. Most surveillance models, including that proposed by WHO (2008), envisage service quality controlled by the supplying agency and independently monitored by a separate surveillance agency. In most countries, the agency responsible for surveillance should be the Ministry of Health and its regional or local offices.

In some countries, a central environmental department may provide surveillance, or it could be decentralized to local government. In the United Kingdom, for example, regulation and surveillance is the responsibility of the Drinking Water Inspectorate, which is part of the Department of Environment, Food and Rural Affairs (Ballance and Taylor, 2005).

Surveillance of the more than 100 000 smaller private suppliers in the UK is undertaken by local government (Shepherd *et al.*, 1997).

Centralized surveillance presents difficulties where large distances and travel times are involved. Centralized surveillance also means there is a physical separation between the surveillance agency and the communities that are being monitored (and are directly affected by unsafe water). The preferred model in these circumstances is surveillance by the local health authority under the guidance of a national health body (Howard, 2002), although independent surveillance of small community supplies in developing countries may be problematic. For example, where local government is the water supplier, separating the function of surveillance is achievable but is not likely to be easy. Legislation establishing surveillance systems should take this into account.

2.4. Legislative implementation and enforcement

Even where appropriate laws, regulations and administrative arrangements are in place, supply of adequate drinking water requires political support and adequate funding and capacity. A common obstacle has been inadequate funding of the primary agencies responsible for regulation and surveillance of drinking water supplies. Without an underlying institutional structure that has both the will and resources to undertake regulation and enforcement, governments cannot implement their drinking water legislation.

Implementation of legislation can be problematic in both developed and developing countries. In a survey of three pilot projects in developing countries, Lloyd and Helmer (1991) noted a lack of strong institutional action. This was also the case in Canada, where a review of an outbreak of *E. coli* O157 and *Campylobacter jejuni* in Walkerton, Ontario found that regulatory authorities were not actively involved, thus contributing to the deadly occurrence (O'Connor, 2002). A review of a 1998 outbreak of cryptosporidiosis and giardiasis in Sydney, Australia, also made a case for increasing regulatory oversight (Clancy, 2000).

Effective implementation requires that all agencies and authorities relevant to drinking water commit and coordinate their actions, although it is generally recognized that the head of the health ministry or department should take a lead role in oversight and surveillance of drinking water supplies and drinking water quality (WHO, 2008; Bartram *et al.*, 2005). Countries should maintain the balance between central government and local authorities.

Decentralization advantageously places governance and support closer to the community and allows for closer tailoring of regulatory actions based on local needs. Legislation needs to provide the authority and autonomy necessary for decentralized operations to function successfully (Appleton, 1995). The UN Millennium Project Task Force on Water and Sanitation also advocates that governments empower local authorities and communities to manage water supply delivery (UN Millennium Project, 2005).

Even with decentralization, there is room for complementary centralized oversight (Howard, 2002; UN Millennium Project, 2005). Centralized government should take the lead on issues such as standard setting, provision of subsidies and actions to improve access to water supplies. Central government should also maintain oversight of decentralized services to ensure that provision of services is consistent with national policies, particularly in relation to the provision of services to the poor.

III. CONCLUSIONS

The MDGs aim to halve the proportion of people without sustainable access to safe drinking water by 2015. Progress is measured by the WHO/UNICEF joint monitoring programme, which assesses access to improved drinking water supplies (WHO/UNICEF, 2004). The issue of safety is dealt with in the WHO guidelines for drinking water quality (2008), which present a framework for safe drinking water and numerical guideline values for hazards to public health. The framework addresses the setting of health-based targets, the management of drinking water supplies through water safety plans and independent surveillance.

The general principles captured in the WHO guidelines can and should be applied universally. However, the framework of the WHO guidelines is not prescriptive, and the numerical limits are not mandatory. Application of the guidelines should be based on national circumstances including local environmental, social, economic and cultural conditions. This includes consideration of existing levels of access to improved sources of drinking water and available resources.

Determining access requirements and setting water quality targets require careful consideration. Standards for drinking water should be supportive and protective of human health but the targets should not be so restrictive that they represent a barrier to improvement. This would particularly

disadvantage the poor, who are disproportionately represented among those without access to improved drinking water sources.

Approaches adopted in developing regions will often be different from those in developed regions, and there will also be differences within regions. Extending access is likely to be a high priority in developing countries, whilst issues relating to management and improvement of existing infrastructure are likely to receive greater attention in developed countries. The approach adopted needs to be delineated in national policies and supported by appropriate legislation, which should be designed to maximize benefits to all sectors of the population. The implementation and effectiveness of the laws and policies should be monitored through an active surveillance programme, and where necessary modified to ensure that required outcomes in the delivery of safe drinking water supplies are achieved.

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Agriculture is the principal human use of water resources in the world, with more water abstracted and used for agriculture than for all other uses combined (FAO, 2009a). Although the world's population nearly doubled between the early 1960s and the late 1990s, global agriculture kept pace through the "Green Revolution", whose investments in surface water storage and groundwater extraction enabled many countries to meet increasing irrigation demands.

Future expansion of food production to meet the needs of growing populations will require greater efficiency in the capture and use of water for irrigation. Whether current irrigation practices will ensure food production sufficient to support future population growth will depend on a number of factors, including application of water control and water-efficient irrigation technologies, use of rainwater harvesting techniques and reclaimed water for agriculture, the amount of irrigated land lost over time, competition for water, alterations in dietary habits, climate change and improvements in crop varieties, amongst others.

This chapter focuses on water in agriculture, particularly on increasing water use efficiency by implementing good practices in irrigation and drainage management. The chapter outlines how irrigation and the quest for water for food production can affect human health and the environment. In view of increasing water scarcity, wastewater will increasingly be a valuable resource as it can help reduce pressure on water resources and provide essential nutrients for crops. It can help increase food production whilst reducing the need for synthetic fertilizers. The goal in regulating wastewater use is to maximize the benefits whilst reducing risks to human health and the environment to tolerable levels.

I. ISSUES IN IRRIGATION

Primary production of food requires water, and nearly two-thirds of all freshwater abstraction worldwide (and up to 90 percent in some countries) is devoted to food production. With the world facing growing food scarcity and rises in food prices, identifying ways to increase food production is a key challenge. Meeting this challenge will require increasing water use efficiency and improving crop varieties as the availability of land diminishes. Water managers and law-makers must balance the need for food with the decreasing availability of water in some areas of the world and the expected risks from climate change.

Sustainability of irrigation depends on applying good irrigation practices, water-efficient technologies and water governance. As an example of the last, in some areas up to eight percent of all food crops may be grown on land irrigated with groundwater that is being abstracted faster than it is being replenished (Postel, 1999). Developing more efficient and sustainable methods for the use of water resources is essential.

This section first addresses the way in which irrigation schemes and society influence the amount of food production and the use of water. Second, it addresses how irrigation affects human health. Finally, the discussion turns to how irrigation and the environment interact.

1.1. Food production

Irrigation can play an important role in alleviating poverty and improving food security through its use in food production. Irrigation schemes have been linked to increases in calorie intake and decreases in the numbers of undernourished people. From 1969 to 1971, the intake per person per day was 2 110 Kcal for developing countries and 2 410 Kcal for the rest of the world. From 1997 to 1999 those numbers increased to 2 680 Kcal and 2 800 Kcal, respectively. At the same time, the number of undernourished people in the developing world decreased from 37 to 17 percent (FAO, 2001a).

Food production's negative impacts on water resources can increase with greater economic prosperity. As societies grow wealthier, meat consumption typically increases. Using water to raise crops for animal feed is much less efficient than using it to produce crops for direct human consumption. Producing a kilogramme of beef requires 8 to 85 times more water (depending on soil and climate conditions and irrigation methods) than producing a kilogramme of grain (see Table 8.1).

Over-grazing of livestock leads to more surface runoff of water, causing soil erosion (and reduced soil fertility), eutrophication and less groundwater recharge. Industrial farming concentrates large numbers of livestock in small areas and produces significant quantities of animal waste, which – if not stored and treated properly – can pollute both groundwater and surface water supplies. Moreover, zoonoses (infections transmitted from animals) are the principal emerging infectious diseases threatening human health (Cotruvo *et al.*, 2004). As societies move from a grain-based diet to a meat-heavy diet, they use more water for food production. Globally, it will be

necessary to develop strategies to use water more efficiently to maintain or increase food production with limited water resources.

Table 8.1 - Approximate¹ Crop Water Requirements to Produce Specific Foods

Crop/Food	Water Requirement (kg of water per kg of food produced)
Potato	500 – 1 500
Wheat	900 – 2 000
Alfalfa	900 – 2 000
Corn/Maize	1 000 – 1 800
Sorghum	1 100 – 1 800
Soybeans	1 100 – 2 000
Rice	1 900 – 5 000
Chicken	3 500 – 5 700
Beef	15 000 – 70 000

Source: Gleick, 2000.

Gleick (2000) estimates that it takes 640 m³ of water per person per year to grow enough food to support the average diet of a person living in Sub-Saharan Africa and nearly three times as much – 1 830 m³ of water per person per year – to grow enough food to support the average diet of a person living in North America (see Table 8.2).

Years of research during the Green Revolution dramatically improved the yield and water use efficiency of many crops. For example, hybrid rice strains were developed that matured earlier and produced approximately three times as much rice per unit of water (Postel, 1999). With more research, further water efficiency gains are possible for some crops. However, even with the adoption of new technologies (e.g. genetic engineering), future increases in yield and water use efficiency for many crops such as wheat or rice are unlikely to be as large as those made during the Green Revolution (Postel, 1999). It may be necessary to focus more research efforts on improving varieties of other crops (e.g. cassava, yams), including some that are important to subsistence-level populations.

¹ These approximate values also vary significantly by region, climate, irrigation methods and other factors.

Table 8.2 - Calories Required for Regional Diet, Percentage of Diet as Meat, Estimated Water Needs²

Region/ Grouping	Calories (Kcal) of Regional Diets (1989)	% of Calories from Meat	Estimated Water to Produce Regional Diet (m ³ /capita/yr)
Africa, Sub-Saharan	2 191	10	640
Centrally Planned Asia	2 541	15	920
Eastern Europe	3 345	28	1 430
Former USSR	3 253	30	1 570
Latin America	2 555	19	1 030
Middle East/North Africa	2 819	13	1 070
OECD-Pacific/Oceania	2 691	24	1 210
South and East Asia	2 485	12	770
Western Europe	3 350	36	1 710
North America	3 133	35	1 830

Source: Gleick, 2000.

1.2. Human health

Although the expansion of irrigation schemes has been an extremely important factor in increasing food production, poorly planned and managed irrigation systems may pose risks for human health. The principal risks derive from limitations to or decreases in food production which may affect food security and thereby nutrition; changes to disease vector habitats which may increase disease risk primarily for nearby populations; and contamination of foodstuffs with infectious agents and toxic chemicals from human, animal and industrial wastes and the natural environment.

The principal contaminant concerns for human health are infectious bacteria, protozoa and viruses deriving from human or animal excreta. Irrigation may also allow agricultural inputs such as pesticides and artificial fertilizers to leach into the drinking water supply with potential health risk if concentrations reach levels of concern.

² Includes both rainfall and irrigation water, and assumes variations in regional irrigation efficiencies.

To help prevent or counteract potential harmful health effects of irrigation schemes, irrigation management should also integrate vector control measures. Vector control should address three components: permanent or long-term modification of land, water and vegetation to control vector breeding and spread; ongoing management of land, irrigation and drainage to produce and ensure conditions unfavourable to vector breeding; and the modification or manipulation of human habitation or behaviour (FAO, 1984). In addition to chemicals and vaccinations, measures such as drainage, aquatic weed control, canal maintenance and lining, water management (including intermittent irrigation practices) and human-vector-pathogen contact reduction measures are important and cost-effective components of an integrated vector control strategy (FAO, 1984).

1.3. The environment

Irrigated agriculture may have both negative and positive effects on water quantity and quality. Irrigation schemes that are poorly planned and managed may result in increased salinization, over-abstraction, degraded water quality and loss of biodiversity. By contrast, good irrigation and drainage practices may result in better, more efficient water use and ecosystem protection.

Poor drainage practices can lead to waterlogging and salinization, causing decreased land productivity. Salinization concentrates salts in the upper soil layers where plants root, and can cause yield decreases of 10 to 25 percent for many crops. Salinization may prevent cropping altogether when it is severe. In East Asia, 6 percent of agricultural land is degraded by salinization, whilst in South Asia 8 percent is affected. For the arid and semi-arid tropics as a whole, 12 percent of agricultural land may be degraded (FAO, 2003). These global statistics often fail to convey the localized impacts of these environmental changes on regional food security and environmental sustainability.

In certain areas, irrigation is associated with surface water and groundwater over-abstraction, which can negatively affect the amenity and ecosystem values of water. Wetlands, for example, have contributed to agricultural growth because their soils are fertile, they contain water for much of the year and they help regulate floods and protect biodiversity. However, many wetlands have been extensively drained, which has seriously damaged the environment. This is one of the many factors that led to the adoption of the Ramsar Convention on Wetlands in 1971 to protect wetlands from over-

exploitation by outlining principles of wise use. According to the convention, sustainable use of wetlands can be achieved by selecting crops adapted to wetland conditions, using appropriate soil and water management technologies and carefully planning wetland development within an entire watershed so biodiversity is protected from any agricultural activities in upstream areas.

Pollutant loads, habitat degradation and massive water withdrawals arising from irrigation and damming have in some circumstances harmed inland fish resources. Degradation of water quality poses a serious problem especially in estuarine and coastal zones at the lower end of river basins where eutrophication, oxygen depletion, habitat loss and pollution from intensive farming systems have had an impact on natural resource sustainability.

Notwithstanding these challenges, irrigation programmes can help reverse negative environmental impacts by promoting environmentally sound uses of water, proper drainage and irrigation practices and biological treatment of waste. Well-planned implementation schemes and other good agrarian and buffer zone practices can enhance water infiltration into the ground and thereby reduce flood runoff – particularly if the soil is not saturated, the ground is not compacted and the irrigation is part of a conjunctive management programme. Reuse of treated wastewater can reduce health risks further downstream. Moreover, subsistence agriculture and agriculture that is not focused on monoculture can preserve agricultural and natural biodiversity. Irrigated land may also help offset carbon emissions, since certain crops can help absorb carbon that is released into the atmosphere.

II. INCREASING IRRIGATION EFFICIENCY

It is increasingly important to improve the efficiency of irrigation practices in order to reduce water usage and loss at all levels of the irrigation system. Measures to increase water use efficiency in irrigation include establishing and enforcing water allocation rights (see Chapter 5); promoting water conservation; implementing more efficient irrigation systems and adopting on-farm technologies that reduce water usage; developing and planting crops that use less water; and using treated wastewater or land treatment processes for untreated wastewater. Devolving certain management responsibilities to users may also serve these ends. In addition, water resources may be used more efficiently in general when they are part of a larger basin-wide management scheme integrating all uses and needs (see Chapter 9).

Irrigated agriculture's largest losses typically occur when water is routed through canals and ditches to farmers' fields. As it travels, water is lost into the ground through seepage and also into the atmosphere through evaporation. Efforts to reuse drainage water and to prevent these losses will result in real water gains (Huffaker and Whittlesey, 2000). Transmission losses can be reduced by filling sinkholes, lining canal bottoms and sides with either conventional concrete or roller-compacted concrete and replacing canals with high-density polyethylene pipe.

The amount of freshwater used for irrigation can also be significantly reduced by introducing new techniques that address precisely how water arrives at each plant (see Box 8.1). Technologies include drip irrigation, efficient sprinkler systems, precision irrigation, timed water application to match plant requirements and the development of new water-efficient crop varieties (FAO, 2001b; Postel, 1999).

Box 8.1 - Methods of Improving Irrigation Efficiency

Improving the efficiency of irrigation systems is essential to addressing problems of water scarcity and improving the management of water allocations in general. However, irrigation efficiency does not only mean reducing abstractions. Rather, it requires a close consideration of how the water reaches each plant. FAO has developed six management "keys" to improving efficiency in irrigation systems:

1. reducing seepage losses in canals by lining them or using closed conduits (including pipes);
2. reducing evaporation by avoiding mid-day irrigation and using under-canopy rather than overhead sprinkling;
3. avoiding over-irrigation;
4. controlling weeds on inter-row strips and keeping them dry;
5. planting and harvesting crops at optimal times; and
6. irrigating frequently with just the right amount of water.

Source: FAO, 2001b.

Low-cost drip irrigation techniques have been introduced in a number of countries. In the early 1990s, FAO set up a pilot project in Cape Verde which was so successful that a number of private farmers adopted the same

drip irrigation techniques. Within six years, 22 percent of all irrigated land in Cape Verde was irrigated with drip systems (FAO, 2001b), and as a result, the production of horticultural crops increased from 5 700 tonnes in 1991 to 17 000 tonnes in 1999 (FAO, 2001b).

These technologies may not be appropriate in all settings, for example where land needs to be prepared or ploughed seasonally. Furthermore, certain technologies may not be appropriate for all farmers: they may be low cost for the average commercial farmer but unaffordable for subsistence farmers, especially considering expenses for system maintenance. Subsistence-level farmers often cannot afford the equipment necessary to use drip irrigation technology and must instead rely on surface water supplies and cruder irrigation diversion systems. For these farmers, more low-cost or low-maintenance technologies or techniques may be appropriate.

Another technique to improve efficiency is deficit irrigation, where crops are not supplied with the full amount of water typically required to achieve maximum growth. Instead the farmer reduces the water application, cognizant of the tradeoffs amongst water availability, plant growth and crop revenue. This approach is particularly useful in arid or semi-arid regions. Field trials have shown that through deficit irrigation, substantial water savings can be achieved with little impact on the quality or quantity of the crop yield (FAO, 2000b). For example, in the North China Plain, water savings of 25 to 75 percent were realized without significant yield or profit loss (FAO, 2000c). On the other hand, a study of potatoes in the United States in the State of Oregon showed that limiting water use had adverse impacts on yields and profits (FAO, 2000a) – demonstrating that techniques that work in one area may not work in another. Still, research on fruit crops in Australia and the United States has shown increases in water use efficiency of up to 60 percent as a result of improved water scheduling (FAO, 2000d; FAO, 2000b).

Water savings during primary production can be achieved by growing more crops during the cool season when there is less evaporation (and in some regions more rainfall) and by better managing fallow land and crops (Seckler, 1996). Water use can also be made more efficient by adapting the water quality to the crop. Seckler (1996) cites an example of using salty drainage water from a crop to irrigate cotton, which is a halophyte (i.e. a salt-tolerant crop). The drainage water from the halophytes – which may have a higher salt concentration than sea water – is then channelled into

evaporation ponds and the salt harvested after the water evaporates. Saline or sodic (i.e. high in sodium relative to calcium and magnesium) water from drainage water is used to produce many conventional grain, forage and feed crops and salt-tolerant plants and trees, particularly in Bangladesh, China, Egypt, India, Iran, Pakistan, Syria and the United States. Recently, as areas have been abandoned for agriculture because of waterlogging and salinity, inland saline aquaculture has been adopted on a small scale in several developing countries, as in the Nile Delta of Egypt (Qadir *et al.*, 2007).

III. USING WASTEWATER FOR IRRIGATION

The use of wastewater for irrigation is widespread in developed and developing countries. Wastewater as discussed here generally refers to wastewater generated by human populations.³ Untreated wastewater is often used in the informal, unregulated sector and directly benefits poor urban and peri-urban farmers who would otherwise have little or no water for irrigation. Much water abstracted from rivers and other water courses contains a significant proportion of wastewater, and “conventional” irrigation from such water courses is for practical purposes a form of indirect wastewater use. Untreated wastewater can improve soil fertility and reduce water contamination downstream (since the wastewater is not fed directly into the water flow but is first filtered through soils during irrigation), but use of untreated wastewater for irrigation presents a risk to the health of the workforce, nearby population and consumers.

This section addresses wastewater management. First, it discusses wastewater’s use as a resource, and then outlines social and equity issues relating to wastewater use. It then examines good practices for maximizing benefits from the use of wastewater in irrigation. Finally, the section outlines the underlying legal and regulatory framework for wastewater and briefly discusses guidelines for wastewater use.

3.1. Wastewater as a resource

Planned water reclamation and reuse for agriculture is a strategy gaining wider acceptance in many parts of the world. In water-scarce countries, wastewater services have become important in attaining the equilibrium

³ Industry-created wastewater may have serious toxicity problems, but with appropriate treatment may become acceptable for irrigation of some crops. Urban sewerage often receives discharges from industrial sources.

between demand and supply of adequate quantities and quality of water. Increasing population and food demand, water shortages and concerns for environmental pollution have made reclaimed wastewater an increasingly valuable resource.

Use of wastewater requires changes in the traditional water allocation systems, funding structures, water-quality standard-setting, regulatory frameworks and institutional mandates. It involves good governance at all levels in order to develop a holistic approach and consistent policies. Integrated water resources management, because it encompasses all aspects of water resources development, management and use, can be usefully applied in the wastewater context. A key challenge will be to consider both basin-wide issues and local needs together.

The concept of a multiple use approach of water can also be useful in incorporating wastewater use into water resource management, since it is based on the conception of one water resource supporting a variety of uses. Deliberately allowing for multiple uses when designing and managing irrigation schemes can protect users' livelihoods and health. A multiple use approach requires (1) assessing water needs in collaboration with end users; (2) examining the water sources available – from rainwater to wastewater to piped systems; and (3) matching water supplies to needs based on the quantity, quality and reliability of water required for the various purposes (IWMI *et al.*, 2006).

Particularly in arid and semi-arid regions, wastewater is often used in irrigation where it represents an important resource for farmers. In addition to its water content, wastewater contains nutrients and organic matter that facilitate plant growth.⁴ At an irrigation rate of two m³ per year (a typical requirement in a semi-arid climate), treated municipal wastewater can supply 300 kg per year of nitrogen and 60 kg of phosphorous. In such cases, supplementary fertilization needs can be reduced or even eliminated for some crops (Mara and Cairncross, 1989) (see Box 8.2). In addition, since wastewater flows are often consistent across seasons, they offer a drought-resistant source of water (Gleick, 2000).

⁴ The nutrients in wastewater can also be useful for aquaculture, which is not a topic addressed in this chapter.

In coming years, population growth will stress water resources, with most population growth expected in urban areas. As urbanization leads to generation of more wastewater, wastewater use can contribute to optimizing water resources and ensuring a dependable year-round supply of water to support urban and peri-urban food production (FAO, 2009a). In Mexico, most of the wastewater from Mexico City is used in irrigation districts surrounding the city (Scott *et al.*, 2000).

**Box 8.2 - Agronomic and Economic Benefits of
Wastewater Use in Irrigation**

A city with a population of 500 000 and water consumption of 200 litres/day/person would produce approximately 85 000 m³ per day of wastewater, assuming 85 percent inflow to the public sewerage system. If treated wastewater effluent is used in carefully controlled irrigation at an application rate of 5 000 m³/hectares/year, 6 000 hectares could be irrigated.

In addition to the economic benefit of the water, the fertilizer value of the effluent is important. Typical concentrations of nutrients in treated wastewater effluent from conventional sewage treatment processes are as follows: 50 mg/litre of nitrogen; 10 mg/litre of phosphorous; and 30 mg/litre of potassium. Assuming an application rate of 5 000 m³/hectares/year, the fertilizer contribution of this effluent would be 250 kg/hectares/year of nitrogen, 50 kg/hectares/year of phosphorous and 150 kg/hectares/year of potassium. Thus, the effluent would supply all of the nitrogen and much of the phosphorus and potassium normally required for agricultural crop production. Other valuable micronutrients and the organic matter contained in the effluent would also provide benefits.

Source: FAO, 1992.

Numerous studies have shown that the use of wastewater for irrigation increases crop yields, but good irrigation practices are essential. They are particularly critical to prevent pathogen transmission, the build-up of trace elements and salinity. Wastewater may contain boron from household detergents but certain crops (such as citrus trees) cannot grow where the water contains even low concentrations of boron. Furthermore, heavy metals may accumulate in wastewater-irrigated soils and must be monitored. Certain

metals have varying degrees of synergistic and antagonistic effects on plants, which have different degrees of tolerance.

Wastewater can help ameliorate the groundwater crisis, which has manifested itself in falling groundwater tables, seawater intrusion and polluted aquifers. Use of wastewater instead of groundwater can reduce the stress on groundwater stocks by providing a suitable alternative and allowing natural recharge of groundwater resources. Groundwater replenishes slowly, and so artificial recharge with treated wastewater has become progressively more important as a means of boosting the natural supply of groundwater aquifers. When water in coastal aquifers is pumped out at excessive rates, salt water from the ocean or sea may flow into the aquifer and replace the extracted freshwater. Treated wastewater may act as a barrier to saline intrusion when it is pumped back into the aquifer, thus preventing the water from becoming brackish and preserving its value for food production.

Artificial recharge of groundwater can be direct or indirect. The former involves injection of treated wastewater into an aquifer via injection wells, whilst the latter relies on spreading of surface water on land so that the water infiltrates through the vadose zone (the unsaturated layer above the water table). The vadose zone acts as a filter, treating water as it passes through the soil until it arrives in the aquifer. Although artificial recharge with wastewater is recognized as a sustainable groundwater management tool, associated health risks must be carefully evaluated and managed especially in groundwater basins used for domestic water supplies.

3.2. Social issues

As competition for scarce water resources becomes more acute, the social issues of wastewater use become more important. Wastewater may be the only water resource available to poor or subsistence-level farmers living in urban and peri-urban areas. Access to wastewater for agriculture helps many poor families meet their nutritional needs at lower cost (see Box 8.3). For example, in the Guanajuato River basin in Mexico, 140 hectares of land are irrigated with raw wastewater from the city of Guanajuato (Scott *et al.*, 2000). The estimated value of the city's wastewater is US\$ 252 000, plus US\$ 18 900 for the nutrient and soil amenity value to farmers. The wastewater used by the farmers in this irrigation scheme is estimated to provide US\$ 135 worth of nutrients per hectare per year. For poor farmers, this is a substantial amount of money that might otherwise have been spent on fertilizer.

Wastewater use can have different social perceptions depending on the context, and this can affect implementation of wastewater management activities. The local context should be considered carefully in determining risk reduction and risk management measures in wastewater use for agriculture. Cultural values with respect to wastewater will differ widely and will affect the design, implementation and success of government regulation.

**Box 8.3 - Wastewater Use in Hyderabad:
Food Security and Livelihoods**

Wastewater from the cities of Hyderabad and Secunderabad in India flows into the Musi River. During the dry season, 100 percent of the flow of the river is sewage from the cities. Due to population growth and over-pumping of the aquifers, wastewater is often the only source of water for irrigation, used to irrigate an estimated 40 600 hectares of cropland. The wastewater is available year-round and allows the cultivation of up to three crops per year. Over 95 percent of the irrigated land is devoted to growing a forage grass – pará grass or *panicum purpurascens* – which is used to feed water buffalo. One hectare of pará grass brings in more money than an equivalent amount of any other crop – e.g. an average of 2 812 euros per hectare per year compared to 833 euros per hectare per year for leafy vegetables. It is estimated that 40 000 people depend, directly or indirectly, on the cultivation of pará grass for their livelihoods.

Most households with livestock in the urban and peri-urban areas use wastewater-irrigated pará grass as fodder and earn income through the sale of milk. Typically, assuming a six-member household owning one buffalo, 25 percent of the milk produced is retained for household consumption and 75 percent sold. In the rural areas, wastewater-irrigated paddy contributes to almost 43 percent of household food consumption. Many of the urban farmers also grow green vegetables and certain fruits, such as lemons, mangoes, coconuts and custard apples, which they retain for household consumption.

Source: Buechler and Devi, 2003.

Stakeholders are generally more supportive of use of wastewater if they are able to identify and understand the benefits of doing so, the problems the

project intends to address and the urgency or need for the change. It will be important to demonstrate that a viable future is dependent on conserving water and preventing groundwater over-exploitation. For stakeholders to have confidence they must be assured that wastewater will be used in accordance with strict public health, agriculture and safety regulations, and will need to be informed of the high level of controls and testing of reused water at various stages of the service chain.

3.3. Potential health effects

The use of wastewater in irrigation has both negative and positive health implications. Domestic wastewater contains a wide range of pathogens that can survive in the environment long enough to be transmitted to humans through water and food consumption (see Table 8.3). Irrigation with inadequately treated wastewater has been linked to disease outbreaks and may also be responsible for some proportion of faecal-oral disease endemic in some countries. On the other hand, the use of wastewater in agriculture may have benefits which are often overlooked or poorly characterized. The risks and benefits of wastewater use are described below.

Table 8.3 - Survival of Various Organisms in Selected Environmental Media at 20–30°C

Organism	Freshwater	Crops	Soil
	(time of organism survival in days unless otherwise indicated)		
Viruses*	< 120, usually < 50	< 60, usually < 15	< 100, usually < 20
<i>Salmonella</i>	< 60, usually < 30	< 30, usually < 15	< 70, usually < 20
<i>V. cholerae</i>	no data	< 5, usually < 2	< 20, usually < 10
<i>E. histolytica</i> cysts	< 30, usually < 15	< 10, usually < 2	< 20, usually < 10
<i>Ascaris</i> eggs	years	< 60, usually < 30	years
Tapeworm eggs	months	< 60, usually < 30	months

* Poliovirus, echovirus and coxsackievirus

Source: WHO, 2006.

3.3.1. Adverse impacts

Domestic wastewater. Poor management of human excreta, including partially treated or untreated wastewater, contributes to the spread of faecal/oral pathogens through contaminated food, drinking water and recreational water. Nearly 6 percent of the total disease burden, or 84 million life years lost per year (expressed as DALYs (disability adjusted life years)), has been attributed to water- and sanitation-related diseases (Prüss *et al.*, 2002). For example, as described in Chapter 6, an estimated 1.6 million persons die every year from diarrhoeal diseases and 5.4 billion cases of diarrhoea every year are attributable to poor water, sanitation and hygiene (Hutton and Haller, 2004).

The use of inadequately treated wastewater for irrigation is associated with a number of infectious diseases. Intestinal worms are the highest risk, along with other pathogens linked to excreta (WHO, 2006). Viruses and protozoa may also be spread from contaminated water to food. Pathogens on produce may remain infectious for long periods of time and cause disease outbreaks far from where the agricultural products were grown. In addition to disease outbreaks, contaminated water and poor hygiene contribute to endemic diseases.

As discussed in Chapter 6, although the nutrients in wastewater can be a valuable resource when used to grow crops, excessive quantities can have harmful effects. If excessive nutrients are introduced into water resources, oxygen is depleted and organisms that require oxygen (such as fish and plants) may not survive. Excessive nutrients can also facilitate the growth of algae, which are in some cases toxin-producing. When ingested or inhaled or when they come in contact with the skin, some of the toxins from such algae may adversely affect human health (Chorus and Bartram, 1999). Toxin-producing algal blooms also adversely affect fish populations.

Industrial wastewater. In many countries, industrial wastewater is mixed with municipal wastewater and used for irrigation. The use of industrial wastewater poses health risks associated with human exposure to toxic chemicals, although the risks are less well understood than those linked to microbial pathogens (WHO, 2006). Industrial wastes may contain toxic organic and inorganic chemicals that can be taken up by crops. The amount of chemicals taken up depend on the types of chemicals and the properties

of the soil, and the health effects will vary depending on the type and amount of exposure to the chemical in question (WHO, 2006).

To minimize adverse health and environmental effects, industrial wastewater should either be treated as a separate waste stream from domestic wastewater or adequately pre-treated to remove toxic substances before discharge to municipal sewerage. An important task for regulators is to identify sources of industrial discharges. Governments may then require identified polluters to clean up their wastes (or to divert them from the municipal waste stream). Alternatively, policy may require that all industrial discharges be treated separately from domestic wastewater.

3.3.2. Positive impacts

When used safely for irrigation, wastewater can contribute to human health by increasing food production and household income. By improving the ability to produce sufficient quantities of nutritious food (through cultivation or purchase), use of wastewater can have a beneficial impact on health at the individual and community levels by reducing malnutrition. Malnutrition affects approximately 800 million people (20 percent of all people) in the developing world (WHO, 2000b) and leads to both stunted physical growth and impaired cognitive development. It can also have long-term effects on the health and social development of a community. In one study, children aged 9 who had suffered severe stunting in the second year of life scored 10 points lower on a standardized intelligence test than children who had not suffered from stunting (Berkman *et al.*, 2002).

In some cases, improving the living standards of the poor through irrigation development may lead to better health even when the irrigation leads to some increase in disease vectors (Van der Hoek *et al.*, 2001). For example, where a rice irrigation scheme had been developed in a village in Tanzania, a study showed that even though the irrigation village had more malaria vectors than a nearby savannah village, there was a lower level of malaria transmission in the irrigation village (Ijumba, 1997). This was because the village with the irrigation scheme had more resources to buy food; children had a better nutritional status; and the villagers were more likely to buy and use mosquito nets (Ijumba, 1997).

Irrigation with wastewater can also reduce environmental pollution. Wastewater that is used for irrigation will undergo some natural purification

as it travels through the soil, ultimately reducing the amount of pollution that enters surface water or groundwater.

3.4. Health-based targets and risk reduction measures

Human pathogens in fields or ponds do not necessarily represent a health risk if appropriate health protection measures are taken. Health protection measures may either prevent pathogens from reaching the worker or the crop, or they may prevent any pathogens on the crop from affecting the consumer (WHO, 2006).

In developing countries, the level of wastewater treatment is typically low, with Sub-Saharan Africa treating less than 1 percent of wastewater generated (UNICEF, 2000). Although the long-term goal is to move from the unregulated use of untreated wastewater to the regulated use of treated wastewater, the medium term strategy in many developing countries is to prioritize affordable and easily adoptable risk management strategies (IWMI & GWP, 2006). Costs are likely to be low in comparison with the construction, operation and maintenance of conventional wastewater treatment plants.

The 2006 WHO guidelines for safe use of wastewater (2006) apply risk management approaches under the Stockholm Framework and recommend defining realistic health-based targets and assessing and managing risks – along the continuum from wastewater generation to consumption of produce cultivated with wastewater – to achieve these targets. This allows for a regulatory and monitoring system in line with socio-economic realities of the country or locality. In line with those realities, a variety of measures are feasible for health protection: (a) wastewater treatment, (b) crop restriction (restricting wastewater use to certain crops), (c) irrigation technique and wastewater application method and (d) human exposure control.

Although in some cases one health protection measure will suffice to achieve health-based targets, it will often be desirable to apply a combination of several methods at the same time (WHO, 2006). For example, although crop restriction may be sufficient to protect consumers, additional measures are needed to protect agricultural workers. The availability and efficacy of the measures will depend on the local circumstances which must be carefully considered before any option is put into practice (WHO, 2006). It is especially important to consider vulnerable groups. Partial treatment to a less

demanding standard may be sufficient if combined with other risk reduction measures to achieve the desired health target.

Health protection measures must use available resources to progressively improve the situation based on risk assessment and risk management (WHO, 2006). Flexibility is important so that measures that are initially effective and cost-efficient can be phased out in favour of other measures as new needs arise (WHO, 2006). Whatever the coverage or time scale involved, implementation should be closely monitored to ensure that the safety measures are achievable, that the health protection measures are functioning as designed and to rectify any mistakes before human contact or consumption results in illness (WHO, 2006).

3.4.1. Wastewater treatment

Several wastewater treatment options are available, including both low- and high-technology processes. Low-technology processes are favoured in most developing countries not only due to lower cost but also simpler operation and maintenance. They can offer a significant reduction in pathogens (FAO, 2009b). Two such options include wastewater stabilization ponds and wastewater storage and treatment reservoirs. Stabilization ponds, which are most effective in warm climates, are the least expensive option and are the easiest to operate and maintain. They hold waste in shallow basins and rely on sunlight, temperature, sedimentation and biodegradation to treat the wastewater. Sedimentation removes protozoan cysts and helminth eggs which remain in the pond sludge. Viruses are removed by adsorption onto solids such as algae. If they settle, the viruses also remain in the pond sludge. Pathogenic bacteria are inactivated by high temperatures, high pH levels or high levels of sunlight or settle into sludge (FAO, 2009b; WHO, 2006).

In Ghana, as in many other countries in West Africa, shallow dugout ponds usually less than 1 m deep and 4 m wide are widely used in irrigated urban vegetable farming sites. In most cases, they are used as storage reservoirs where surface runoff and wastewater effluents are channelled. Other variations include the use of mobile drums and other reservoirs, which are common in areas where irrigation water sources are distant from farm sites. During the storage of water and its gradual use in irrigation, sedimentation takes place and is very effective at removing helminths (i.e. reduced to less than 1 egg per litre) when sedimentation is allowed for 2–3 days, and this improves the irrigation water quality (FAO, 2009b). Many developing

countries employ additional low-cost measures to enhance sedimentation or to enhance pathogen die-off (FAO, 2009b).

High-technology processes usually involve engineered systems with relatively higher flow rates and lower retention times. The primary treatment step settles solids in a tank where the wastewater is held for two to six hours; this treatment may also be chemically enhanced. The secondary treatment allows for biological treatment of organic substances with liquid and solid separation. If necessary, a tertiary treatment step may be used to remove any specific contaminants, followed by disinfection. Dual membrane (micro-filtration and reverse osmosis) tertiary treatment has been considered to obtain the highest quality recycled water (EC, 2006). Although expensive, it is suitable for high-value cash crops and is used prior to groundwater recharge.

The downside of these processes is that they require initial capital for the complex infrastructure, which is expensive to build and maintain. Furthermore, the more advanced processes remove nutrients that may be useful for agriculture, including nitrogen, phosphorous and organic matter (FAO, 2009b; WHO, 2006). Some treatment processes may have limited efficiencies in removing pathogens of potential health concern.

Wastewater is generally treated to be fit for the prospective use. The choice of treatment will depend on a range of factors such as the potential for human contact with the irrigated water and the end use of the crop (such as whether it is eaten raw or cooked, peeled or unpeeled and used for fodder or industry). Cost will also be an issue.

3.4.2. Crop restriction and crop selection

Crop restriction consists of restricting wastewater irrigation to certain types of crops, such as non-food crops (biofuel and industrial crops, e.g. cotton), crops that have to be processed before consumption or crops that have to be cooked. However, crop restriction is not an adequate control measure on its own. To protect farm workers as well as consumers, crop restriction should be complemented by other measures such as partial wastewater treatment, controlled application of the wastewater or human exposure control (Mara and Cairncross, 1989).

Crop restriction is relatively simple to implement but is only practical under certain conditions. In particular, it is easier to enforce crop restrictions on a small number of bodies (such as private firms, cooperatives, state farms, water user associations in irrigation districts, or municipal authorities) than on a large number of small farmers. If there is no local experience in crop restriction, its feasibility should be tested in a trial area before being implemented on a wide scale. The trial should also include measures that provide a clear initial estimate of the resources required for enforcement, as well as clarifying the most suitable institutional arrangements for implementation.

Crop restrictions can be hard to implement if necessary conditions such as law enforcement, market pressure and demand for clean produce are not in place. So although there have been successful crop restriction schemes in Chile, India, Mexico and Peru (Buechler and Devi, 2003; Blumenthal *et al.*, 2000b), this has not been possible in other countries where wastewater irrigation is more informal (Scott *et al.*, 2004).

Crop selection can reduce human health risks as some crops are more prone to contamination from pathogens, salinity and toxicity than others. For example, some crops (e.g. low-growing plants and tubers) are more prone to pathogen contamination because their edible parts are more exposed to contaminated soils and irrigation water. In view of reports of food safety outbreaks, the Committee on Food Hygiene of the FAO-WHO Codex Alimentarius Commission convened a meeting of experts in 2007 to provide scientific advice regarding potential public health and trade concerns related to fresh produce. The expert group identified leafy vegetables and herbs as raising the most concern (Codex, 2009). With outbreaks persisting in 2008 and 2009, FAO and WHO began collecting information from national food safety authorities in order to continue refining the risk-based criteria, the list of fresh produce commodities of concern and their relative priority (Codex, 2009).

3.4.3. Wastewater application methods

Because of the potential health and environmental effects of wastewater use, careful application methods are required. Farmers may need encouragement and help to change their irrigation methods, and agricultural extension services can provide that assistance.

Irrigation water, including treated wastewater, can be applied to the land in several ways: by flooding (border irrigation), which wets almost all the land surface; by furrows, which wet only part of the ground surface; by sprinklers, which wet the soil in much the same way that rain does; by sub-surface irrigation, which wets the surface little, if at all, but which saturates the sub-soil; by localized (trickle, drip or bubbler) irrigation, which applies water to each individual plant at an adjustable rate; or by sub-surface partial rootzone drying irrigation, which wets part of the root system whilst the other part is dry or drying (and alternates the two parts).

Certain application methods are safer and more efficient than others. Flooding may be the easiest and least costly, but it also carries the greatest potential health risks. Farmers may have to change existing wastewater irrigation methods to reduce risks. However, implementation of alternative methods will require additional work and expense. For example, to implement furrow irrigation, farmers may need help levelling the land or contour ploughing to create the furrows.

Other irrigation methods may be more efficient, particularly when limited quantities of water are available. However, sprinkler irrigation demands careful measures to protect the workforce and nearby residents from exposure to infectious agents. On the other hand, since sprinkler irrigation is most often practised in large, centralized schemes run by a single body, these producers or institutions are in a relatively good position to ensure that protective measures are implemented (Mara and Cairncross, 1989).

Sub-surface or localized irrigation can often protect best against contamination, use water more efficiently and produce higher yields. These methods are expensive, however, and reliable wastewater treatment is required to prevent clogging the small holes (emitters) through which water is slowly released into the soil (although this is not a problem when bubbler irrigation is the method used) (Mara and Cairncross, 1989).

The timing of wastewater application may help minimize negative impacts. For example, applications may be timed and combined with other application and exposure control methods to facilitate the die-off of pathogens. The amount of time necessary depends on the climate, because pathogens die off more rapidly when the weather is hot and dry and more slowly in cool or wet weather (WHO, 2006). One of the most widely documented field water management measures is cessation of irrigation a

few days before crops are harvested to allow for pathogen die-off due to exposure to unfavourable weather conditions such as sunlight (Shuval *et al.*, 1986). As much as 99 percent reduction in detectable viruses has been reported after two days' exposure to sunlight (Feigin *et al.*, 1991). In such systems, regulations require a suitable interval between irrigation and crop handling (Feigin *et al.*, 1991).

3.4.4. Human exposure control

The major challenge for wastewater use is to minimize the risk to human health. Four groups of people are at particular risk from the agricultural use of wastewater: agricultural field workers and their families; those living near the affected fields; crop and meat handlers; and consumers of crops, meat and milk.

In many countries, existing legislation governing occupational health requires employers to protect agricultural workers from exposure to diseases. Employers may need to be made aware of these laws and may need guidance on the protection measures they must take, such as issuing protective clothing (e.g. special footwear and gloves) to farm workers. Concurrent efforts must convince employees to wear this protective gear.

Workers and their families are most likely to live close to agricultural fields and thus local communities are exposed to disease in several ways. They may use contaminated water for drinking or domestic uses, and children may play in contaminated water (WHO, 2006). Extensive irrigation may also lead to increased vector populations and increased risk of vector-borne diseases. It may be necessary to establish physical barriers preventing access to raw wastewater-irrigated fields. Providing safe recreational and bathing water may also be considered (WHO, 2006).

Exposure control fits into a general programme for occupational health when dealing with agricultural employees who work for a limited, identifiable number of employers. It is more difficult to implement exposure control measures for petty traders who sell or make products from the crops produced through wastewater irrigation, unless they can all be found at markets, which are subject to public health inspection. Market inspections may also be good opportunities to advise consumers about the hygienic precautions they should take with the food they purchase to protect themselves from exposure to infection.

Food hygiene should be included in health education campaigns. Consumers should be taught food washing or preparation techniques that reduce pathogen transmission. Crops that are eaten raw as well as crops with hairy, sticky or rough surfaces are more likely to contain pathogens. Certain techniques, such as vigorous washing in a disinfectant or detergent solution or peeling fruits and root vegetables, can significantly reduce contact with pathogens (WHO, 2006). Risks to consumers can be further reduced by thoroughly cooking vegetables and meat, boiling milk and maintaining high standards of personal and kitchen hygiene (Mara and Cairncross, 1989).

Measures to protect human health include providing adequate water supply and sanitation and encouraging hygienic behaviours such as hand washing. Controlling the exposure of workers to faecal contamination in the fields may have little effect if they are exposed to infection from their drinking water and in their home environment. Care must be taken to ensure that the use of wastewater does not contaminate nearby wells or other sources of drinking water.

3.5. Available legal and regulatory controls

Wastewater use for crop production, although common in certain regions, may not be officially recognized or regulated by health authorities. Experience in many developing countries has shown that simply banning wastewater use in irrigation has little effect either on the level of public health risk or on the prevalence of use. This is unlikely to change since the amount of wastewater generated and used will continue to expand along with increasing urbanization. Banning wastewater use is not only unlikely to stop it but may also make supervision and control more difficult. A better approach is to acknowledge that such practices are occurring and support education and promotion on good irrigation practice and health and food safety awareness.

Safe wastewater use requires a strong regulatory framework to maximize the benefits of its use in light of environmental and health risks. The legislative framework should be accompanied by supportive regulatory measures, incentives, coordinated oversight and enforcement.

Legislation

Legislation for wastewater often goes beyond the purview of basic water resource legislation. Certain provisions related to irrigation may fall within a basic water law, whilst provisions related to health will be found within other legislation, such as for drinking water or for occupational safety. At a minimum, governments must ensure that the legislative framework contains essential provisions on irrigation and wastewater and has few overlaps or gaps.

Some jurisdictions enact specific legislation that covers the full range of issues relevant to wastewater treatment and use. The legislation defines and clarifies the responsibilities and roles of state agencies with respect to wastewater, including mechanisms for coordination. In addition, as with other areas of water resource law, the legislation specifies rights of access to and ownership of wastewater, including related land tenure issues. Provisions on environmental protection will also be important. Finally, wastewater legislation must be harmonized with legislative provisions on health, particularly with respect to water quality, occupational health and food safety (WHO, 2006). These principal features of legislation on wastewater are discussed in detail below.

Agency roles and responsibilities

Wastewater legislation touches on both health and environmental issues and thus implicates a wide range of state agencies, including ministries responsible for health, agriculture, education, environment and water resources. Legislation addressing wastewater use must specifically designate which agency is responsible for each area of regulation. In addition, legislation may set up a body to coordinate all agencies involved (WHO, 2006).

Local governments and organizations may also have a role in wastewater use, especially if they are charged with issuing permits and monitoring compliance with wastewater rules or carrying out food inspections at markets. In countries that have decentralized or devolved water management, legislation must establish the division of responsibilities between national and local authorities in wastewater use.

Access rights

As explained in earlier chapters, granting permits or licences and access rights provides farmers or other water users with an important sense of security. This security is particularly crucial for wastewater irrigation practices, as farmers may not develop infrastructure necessary to safely use wastewater unless they are assured of a continued right of access (WHO, 2006). Access rights may be regulated through issuing wastewater use and discharge permits.

Environmental and health provisions

Specific provisions to avoid environmental degradation are necessary. For example, in areas where flooding with wastewater is practised, legislation must provide for measures to avert or minimize harm to nearby water sources, which may be affected by runoff from agricultural fields. Measures may include requiring natural barriers between agricultural fields and water sources or restricting the use of wastewater in sensitive areas or at critical times.

Provisions to avoid environmental degradation may also be necessary where the cost of treating wastewater to limit the salt content is too high. Legislation can control the amount of salt entering the wastewater stream at the point of generation. Egypt, for example, has had success limiting the salt content in its wastewater by regulating the contents of domestic detergents and industrial effluents (WHO, 2006).

Some health issues resulting from wastewater use may best be dealt with in legislation dealing with health and worker safety. Health provisions should set forth requirements for inspections of crops and food products made from crops irrigated with wastewater to ensure that they are safe and to ensure the safety of the workers preparing or selling the food products. Laws may mandate that safety inspections may occur at the field level, the manufacturing level or the market level. As already noted, employers may be required to ensure farm worker safety by providing protective clothing and equipment or taking necessary health protection measures for workers dealing with wastewater. Finally, governments may need to conduct a health impact assessment (HIA) before creating a wastewater use system. (see Chapter 3.)

Regulations, guidelines and standards

In certain contexts, implementation and enforcement of regulations may be difficult, particularly in view of resource, capacity and financial constraints. It is therefore critical that new regulations plan and provide for the institutions, staff and resources necessary to ensuring that the rules are fully adhered to. Regulations should be realistic and achievable in the context in which they will be applied.

Implementation of guidelines for safe use of wastewater will best protect public health when integrated into a comprehensive public health programme that includes other sanitary measures, including personal and domestic hygiene education, outreach and behavioural change. Farmer field schools can impart information about good agriculture and irrigation practices and hygiene.

Specific scientific requirements should be based on guidelines and standards such as those elaborated by WHO and FAO. In setting standards at national level, local circumstances should be taken into account so that realistic targets can be set and achieved. Incremental progress is to be expected.

Microbial standards

Different microbial standards for wastewater use in agriculture have been developed worldwide. Based on an approach that used empirical epidemiological studies, microbiological studies of the transmission of pathogens and quantitative microbial risk assessment, WHO created guidelines for safe use of wastewater in agriculture (Blumenthal *et al.*, 2000; WHO, 2006). These should form the basis for regulations dealing with wastewater use.

Chemical standards

As discussed earlier, industrial wastewater is often mixed with municipal wastewater, which is then used for irrigation. The health risks associated with chemicals found in wastewater and sludge must be given more attention, particularly as industrialization increases in developing countries. WHO has developed standards for a selection of harmful chemicals that might be found in wastewater (WHO, 2006). In many situations, the safety of the wastewater for irrigation will need to be determined on a case-by-case basis,

depending on the type of chemicals suspected to be present. Chemical analysis of the wastewater may be necessary.

IV. CONCLUSION

Agriculture is the chief user of water resources worldwide, and there is little doubt that the use of wastewater for irrigation will be important in meeting the world's rising food needs. The use of wastewater can help redress growing water scarcity and improve food production but it requires a comprehensive regulatory framework to maximize the benefits of its use whilst taking into account human health and the environment. Wastewater irrigation must be governed by a legislative framework underpinned by science-based guidelines, accompanied by effective risk management and implemented in tandem with public education campaigns.

As a final note, law-makers should recognize that in some cases, imposition of overly strict water quality standards for wastewater could paradoxically lead to the use of water that is less safe. In countries with inadequate resources for wastewater treatment or enforcement, farmers and producers may simply ignore standards that they are not physically or financially able to comply with. Realistic guidelines should be adopted that match the social, economic and environmental conditions of each jurisdiction.

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INTEGRATED MANAGEMENT OF WATER FOR HUMAN AND ECOSYSTEM NEEDS*

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As outlined in earlier chapters, human development has depended on a variety of consumptive and non-consumptive uses of water, some of which have caused adverse effects on ecosystems through alterations to the natural water cycle. These alterations have, however, allowed the provision of welfare-enhancing services to society. A critical challenge is therefore the need to strike a balance between the use of water for human development and the use of water for ecosystem management.

This chapter introduces the concept of ecosystem uses of water alongside human uses. Governments have traditionally dealt with ecosystems by regulating water use, setting quality standards and defining maximum limits for polluting agents. The broad objective has been to maximize human benefits whilst respecting certain constraints related to the degradation of ecosystems and the protection of human health. By contrast, integrated water resource management embraces a more holistic approach to water, recognizing its myriad facets and uses, managing water at the watershed level and taking into consideration both groundwater and surface water and the interconnections between them.

This chapter begins with a review of conventional water resources management – of watersheds, groundwater and surface water – and the concomitant misallocation, overuse and pollution of water resources. It then discusses how to create an enabling environment for a more holistic management model. The last section outlines available regulatory and market mechanisms that can induce changes in users' and polluters' behaviour so as to increase the productivity of water across the full range of human and ecosystem uses.

I. WATER RESOURCE MANAGEMENT

Water management has traditionally focused on single water uses without considering the impact of management decisions on the water cycle as a whole and therefore on other legitimate uses. The lack of a wider lens has led to conflicts between users and to deterioration of freshwater sources at the watershed, groundwater and surface water levels. The next sections examine elements of water management, including watershed management, groundwater management and surface water management.

1.1. Watershed management

Watershed management covers both water resources and land use management, recognizing that land use has an impact on the water cycle and on downstream water quantity and quality. For example, the harvesting of timber resources will affect the quantity and timing of downstream water yield and may lead to erosion and downstream water quality problems (Bruijnzeel and Critchley, 1994). On the other hand, restoration or protection of wildlife may increase the risk to municipal water supplies from biological pathogens such as giardia and cryptosporidium, which are carried by wild animals (NRC, 2000).

In a watershed, land management upstream is linked to human welfare and ecosystem function downstream. Land use and land use management affect the water cycle in several ways but principally by altering the vegetation cover and thus changing the properties of the soil. This affects a variety of hydrological functions including (a) precipitation; (b) annual water yield; (c) seasonal flows, particularly baseflow; (d) groundwater recharge; (e) storm flow response or flood flows; and (f) runoff and leaching of chemical and biological pollutants. Good watershed management means ensuring that changes in downstream (off-site) hydrological services are included in the decision-making process of the land manager, along with the costs and benefits of the on-site hydrological services.

Public agencies or councils may adopt watershed management by introducing incentives to promote, amongst private land owners, land and water management measures that preserve the ecosystem of a given watershed. Upstream land managers are usually concerned about soil erosion to the extent that it affects on-site productivity of the land. Too much erosion may indeed lower plant yields, giving the land manager an incentive to invest in soil conservation measures. However, a private land manager will never pursue the minimum possible erosion rate but rather define an acceptable rate of erosion that is consistent with maximizing long-term profit from the land (McConnell, 1983).

Although the erosion produced upstream travels downstream as suspended sediment (thereby decreasing downstream water quality and increasing water treatment costs), there is no incentive for the upstream land manager to reduce this economic impact. The behaviour will continue until the land manager is either forced to adhere to some other standard or technology or is

provided with some positive or negative incentive that encourages a reduction in the erosion rate. Watershed management in this case may include the identification of new incentives for the upstream land manager in order to ensure both on-site productivity and lower water treatment costs downstream.

1.1.1. Land use and downstream hydrological change

Land use and land use management practices may alter (a) the quantity of precipitation that is intercepted and evaporated from surfaces (particularly vegetation but also soil); (b) the quantity of water that is transpired and evaporated by plants; (c) the rate at which water infiltrates the soil and hence the level of surface runoff; and (d) the runoff or leaching of materials, nutrients and pathogens into groundwater and surface water. These land and water interactions can be complex.

In many locations, the actual changes in flow, quality and timing are difficult to predict or ascertain with any degree of certainty, but generally, removal of natural vegetation and disturbance of soil will worsen water quality (Bruijnzeel, 2004). For water quantity, the causal relationships are not as well understood. The effects of land use and vegetation on water quantity are currently being debated by scientists and disagreement is widespread (see Box 9.1). Many scientists suggest that vegetation cover with high rates of interception and transpiration (such as certain forests and crops) evapotranspires (or consumes) more water than other types of land cover. This means that the annual water yield may actually increase under a different land use because of increased water runoff and a possible increase in water infiltration into the soil.

However, it is important to consider not only the total water flow but also the possible alterations in the minimum flow rates during dry periods and in the maximum flooding rates during wet periods. A change in those peaks of water availability may have a greater downstream impact than an increase in the annual water yield. In this regard, a land use change involving deforestation may result in soil compaction, which in turn would reduce the water infiltration rate and subsequent groundwater recharge. This could result in a reduced dry season baseflow. But even in this case, scientific evidence suggests that as long as the deficit in groundwater recharge does not exceed the increase in the annual water yield caused by reduced evapotranspiration, even drastic land use changes such as forest to pasture may lead to a higher dry season baseflow.

Box 9.1 - Conflicting Views: Water Yield, Groundwater Recharge, Seasonal Flows and the “Sponge” Effect

When human activities reduce the vegetation cover (e.g. by deforestation), the rate of evapotranspiration is also reduced. This is the case in both temperate and tropical regions (Bosch and Hewlett, 1982; Bruijnzeel, 2004), but it goes against the popular perception that forest areas “produce” more water than non-forest areas. Although it is true that forests naturally grow where there is more precipitation, it is precipitation that causes forest and not the other way around. Forest areas might actually “collect” more water than neighbouring non-forest areas but they deliver less due to their higher evapotranspiration rates. In this regard, the scientific community is fairly unanimous in stating that more water runs off and infiltrates into the ground in areas with lower evapotranspiration (Bosch and Hewlett, 1982).

Human alterations of natural vegetation have a less clear-cut impact on seasonal flows, particularly on dry season baseflow. Theoretically, lower levels of evapotranspiration following vegetation removal can cause dry season baseflow to rise because of a higher water runoff and possibly a high infiltration rate. However, this response may be reduced or even reversed if soils are so compacted by the subsequent land use that infiltration of precipitation is significantly curtailed (i.e. a reduction in the so-called “sponge” effect). Most scientific observation to date reveals that more often than not the removal of forest leads to a fall in dry season baseflow (Bruijnzeel, 2004).

Although this conclusion seems to confirm the existence of the “sponge” effect of forest cover, current scientific understanding of forest hydrology argues against reliance on this effect as a basis for management and policy decisions (Aylward, 2005). Furthermore, research has shown that the hydrological impact of land use changes is caused not only by the initial intervention but also by the subsequent type of land use and the management regime applied (Bruijnzeel, 2004). Hence, the popular perception that the alteration or removal of natural vegetation automatically leads to reduced water availability and lower dry season flows should not be overstated.

1.1.2. Precipitation and rainwater harvesting

Rainwater harvesting is the act of trapping precipitation for future use in domestic, farm or other activities. Typically it is implemented at household or commercial-building scale or for industrial purposes. Impermeable surfaces such as tin or other roofing materials are used to collect rainwater, which is funnelled through drainpipes or other means into above- or below-ground storage containers for future use. Other less common examples include the preparation of wind breaks (using natural or human-made materials) to capture fog. Rainwater harvesting is often portrayed as an innovative solution in water management – even a viable alternative to building dams for storage (WCD, 2000).

Where a household adopts a harvesting system in place of direct pumping or withdrawal of water from a water body, this may have no net impact on the water cycle. On the other hand, if the convenience and low operational costs of rainwater harvesting lead users to expand their use and consumption of water, there may be an overall increase in net use and consumption by the household. In this case, rainwater harvesting by an upstream water user may deprive users downstream. On the other hand, in the rare cases where precipitation runs off the land or into an aquifer and has no further human or ecosystem use downstream, rainwater harvesting can be a sustainable option.

1.1.3. Unresolved issues

Whatever the exact hydrological impacts in a specific locale, it is clear that land management actions and rainwater harvesting by upstream land managers, households and industry have the potential to impair access to and quality of water for downstream users. Where downstream hydrological goods and services are in scarce supply, these changes may have important social and economic impacts. In the case of land management, the problem lies in the fact that land use regulations do not require upstream land managers to integrate the downstream impacts of their decisions (or the preferences of downstream users) into the decision-making process. In the case of rainwater harvesting, depending on the national system, in most cases the technique is largely unregulated.

Chapter 5 introduced types of resources and identified land use and rainwater harvesting as a common pool resource. This classification stems from the inexorable pull of gravity, which causes both positive and negative changes in

water quantity and quality to move inevitably down-gradient. From the perspective of the upstream land manager, it is difficult to prevent downstream users from enjoying any benefits of action taken to improve land management and consequently water supply and quality. Equally, the downstream user is effectively at the mercy of the upstream land owner. An upstream land manager may capture additional water for household and industrial use or may plant a crop with higher water use requirements, which affects the quantity and quality of prior and profitable downstream uses of water. This is despite the fact that in many situations headwater areas are less productive and the water would have had a higher productive value in downstream uses. Moreover, agricultural activity downstream may be an important livelihood or source of food security for local communities, and downstream users may have made significant investments in infrastructure based on the expectation of continued access to clean and abundant water supplies. It is clear in these cases that the upstream land manager's actions may have a significant social and economic impact on downstream communities.

In this case, location (i.e. upstream vs. downstream) defines the problem. The inability of the downstream community to prevent the upstream land manager from taking certain actions is likely to lead to a less than optimal use of the water resource from a social perspective. It can lead to a first-come, first-served situation, akin to that of an open access fishery, with upstream fishers having the advantage. In this case, as described in Chapter 5, market failure occurs due to the problem of excludability.

Regulation of surface water use is the first step towards conflict resolution. The regulatory framework should provide the means to protect prior consumers of water and users of hydrological services. This may be easiest where water is considered a public good to be managed by the state in the interest of the population. The state grants users permits for the diversion and use of the water, which gives legal certainty and security to the rights and obligations of all riparian users, both upstream and downstream. On the other hand, where the regulatory system was devised to solve the open access problem amongst surface water users, it may not function well in a conflict between surface water users and rainfall users. The upstream users still risk harming the downstream community and imposing net costs on society. Recognition of this problem is only slowly emerging and initial efforts to address it will be reported later in this chapter.

1.2. Groundwater management

Aquifers can be defined by their rate of inflow (from land and surface waters), by the quantity of water held (actual and potential) and by the rate of discharge (to surface waters or the ocean). Where the stock of water held in an aquifer is small relative to the annual inflow and outflow, the aquifer may be considered an underground river. Conversely, when the stock is several times the annual inflow and outflow, the aquifer may be defined as an underground storage reservoir. Aquifers thus have different naturally occurring physical characteristics that present differing management challenges. The next sections examine the features of each type of groundwater system.

1.2.1. Groundwater as a river

Groundwater can be considered an underground river in that the water is routed through the earth and then back out as discharge into surface waters or the sea. This can occur at different time scales. In some headwaters or along a narrow river valley, runoff or surface water may infiltrate into the ground only to appear as surface water a short time and distance further downstream. Alternatively, groundwater recharge in the headwaters of a large basin may take hundreds of years to be pushed through the earth by hydraulic pressure and then appear many miles downstream.

In natural conditions, groundwater is a renewable resource in that each year new precipitation percolates through the ground to become groundwater and groundwater discharges to surface water. Groundwater pumping interrupts this process and can create temporary drawdowns and deficits in this underground flow. In extreme cases, the pumping may suck up the entire underground river and temporarily stop the flow emerging at the point of discharge. Even so, the resource remains renewable since the underground river does not store water.

1.2.2. Groundwater as a reservoir

Considering groundwater an underground reservoir suggests different physical and therefore economic characteristics. In this case, the aquifer does not regularly discharge its waters back to surface waters: it only does so to drain excess water when it is full. Thereafter, until reaching an equilibrium where recharge equals discharge, the annual water recharge will keep filling the reservoir without any return flow to surface waters.

Reservoirs of stored water may have formed in hundreds if not thousands of years where inflow exceeded outflow. In economic terms, the storage in the reservoir represents stored capital. The capital can be maintained when groundwater pumping and any other outflow do not exceed the annual recharge. An alternative policy would allow the capital to be drawn down by generating annual income over time without regard to the regeneration rate of the aquifer. This income would be in addition to that generated by the use of excess natural recharge (i.e. the water flowing out from the full aquifer). In such cases groundwater reservoirs are considered exhaustible resources (like oil reserves) in that a high level of demand for the resource may lead to an extraction rate that ultimately depletes the stored water.

For economists the question of whether or not to exhaust an aquifer and then turn to other supplies has been a question of academic interest (Koundouri, 2004). For others, particularly practitioners, the risk of exhausting the resource is often a catalyst for improved management. Indeed, in an interesting study of Southern California the net benefits of managing the resource and avoiding exhaustion have been shown to be considerable (Blomquist, 1992).

1.2.3. Unresolved issues

Traditional water management has done little to limit groundwater pumping and protect aquifers. This situation has led to several problems:

- over-exploitation of groundwater reservoirs;
- conflict between competing groundwater users (i.e. extraction by one party negatively affecting the other party by drying up their well or lowering the water table);
- reduction in surface water discharge that has led to ecosystem degradation or harm to existing downstream human uses.

The causes of these problems can be traced back to a number of market and policy failures. First, the failure to plan and adequately regulate the off-take from groundwater reservoirs has led to a common pool resource situation. With no ability to exclude others from accessing the reservoir, each user has every incentive to use as much water as fast as possible. Second, the lack of integrated regulation of groundwater and surface water means there is little consideration for the linked impacts. The lack of groundwater regulation can

also lead users of regulated surface water to turn to unregulated groundwater as an alternative, with additional negative effects.

Given its status as a renewable resource with elements of exhaustibility, groundwater needs to be managed so as to maximize the benefits in the presence of climate variability. The focus of management has often been on managing the inflow of water and the reservoir function of an aquifer for the purposes of sustainable extraction of groundwater, with much less attention paid to the discharge portion of the relationship. In the Southern California example just noted, for instance, the need to ensure that the reservoir was robust enough to prevent saline intrusion from the ocean was indeed part of management objectives (Blomquist, 1992). But little interest has been shown in ensuring that discharge from aquifers into surface waters supports ecosystem needs and other downstream uses (Glennon, 2002; WWP, 2007).

1.3. Surface water management

The development and use of surface waters over the last few centuries, and in particular in the twentieth century, has modified the hydrological regime and associated inland freshwater ecosystems in four principal ways:

- ecosystem simplification as, for example, in the American West where the eradication of beavers and beaver dams, the channelization and dredging of streams, the draining of wetlands and the removal of riparian vegetation reduced water storage, decreased evapotranspiration and increased the “flashiness” of the hydrograph (i.e. its rising to a high peak after rainfall);
- damming and diversion of waters from creeks, streams and rivers primarily for irrigation purposes but also for domestic, industrial and commercial use, which reduced or dried up the streamflow, increased groundwater recharge rates from canal- and ditch-transmission loss and on-farm inefficiencies and raised evapotranspiration rates on land;
- damming and impoundment of waters in large reservoirs for irrigation, hydropower and flood control, which increased evaporation and groundwater recharge rates at the reservoir sites and also greatly modified the flow regime, in some cases inverting the hydrograph (i.e. reducing streamflow during wet months below the reservoir level as water was stored and then increasing streamflow in dry periods as water was released);

- damming and impoundment of waters in large run-of-river reservoirs for hydropower, which altered the daily and weekly hydrological regime and effectively blocked migration of anadromous fish.

The cumulative impact of all of these changes on the hydrograph and on freshwater ecosystems has been extensive and far-reaching. A study of 227 river basins around the world found that 37 percent were strongly affected by fragmentation and altered flows and another 23 percent were moderately affected (Revenga *et al.*, 2000). The Millennium Ecosystem Assessment expects that 50 percent of inland freshwater habitat was lost in the twentieth century (Finlayson and D'Cruz, 2005).

During the time that these modifications to the hydrograph were taking place, impacts on inland freshwater ecosystems were not a major societal concern. But as the countries that developed their water resources prospered, the impacts multiplied and deepened and today are recognized as major environmental issues. This awareness is a product of both a utilitarian drive to protect and restore these systems for human use and a pure sense of biodiversity and natural heritage stewardship. As more countries grow and develop their water resources, awareness of the potential problems with altering the hydrograph is growing. There is also increasing recognition that some of the modifications (such as species extinction) are irreversible and the costs of after-the-fact ecosystem restoration, even where possible, are large.

The primary market and policy failure is not including environmental flows as a recognized use of water, instead mediating only amongst human uses. Downstream ecosystems that depend on a given surface water flow are accorded no standing nor can they adapt to or alter decisions by upstream water users. Environmental flows have naturally been chipped away at and degraded, leading to the present perilous state. The next sections examine emerging solutions to resolving these and other failures.

II. IMPROVING REGULATORY SYSTEMS

As should be clear from the review just made, the main weakness of most existing regulatory approaches is their failure to include the different types and uses of water in a single framework. Emerging approaches to improving water resource management attempt to include all components of the water cycle. The next three sections explore three ways that jurisdictions have attempted

to regulate the whole water cycle: through environmental flows, conjunctive management and exempt uses.

2.1. Environmental flows

Although the term “environmental flow” may be of recent origin, concerns over river health and function have been voiced in many developed countries for over half a century. Still, few countries have incorporated into their legislation provisions for maintaining flows for ecosystems (Dyson *et al.*, 2003). Fewer still have provided the regulatory framework needed to actively restore degraded systems. In many developing countries, management remains focused on such goals as ensuring a supply of water or building infrastructure to meet water demands. Little time or energy has been directed at managing water for the environment’s benefit. However, initial efforts are under way in many developing countries to take account of environmental flows, and the following examples should provide useful guidance.

2.1.1. Protecting flows in intact river systems

In the United States of America, instream flows are protected under the Wild and Scenic Rivers Act (WSRA),¹ which protects certain rivers and streams (or portions of rivers and streams) from obstructions that impede the free flow of water. The goal, as the United States Congress declared, is to protect those rivers that “possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values” (sec. 1271). A river is eligible for protection if it is free-flowing and if it and its adjacent land area possess some of the values mentioned above (e.g. scenic or recreational values) (sec. 1273(b)). In addition, in some circumstances, the river may be eligible if it can be restored to a free-flowing condition.

The WSRA divides eligible rivers into three categories: wild, scenic or recreational. A wild river or stream will generally have to be unpolluted and as close to pristine as possible. It must also not have any impoundments and must be inaccessible except by trail. A scenic river must also be free of impoundments but may be accessible by roads in certain places. For the most part, a scenic river would be primitive, with undeveloped shores. Finally, a recreational river must be easily accessible and might have some shoreline development and a past history of impoundments or diversions (sec. 1273(b)(1)–(3)).

¹ U.S. Code, Title 16, Chapter 28 (as amended, 2008).

The federal government is subject to both prohibitions and obligations under the WSRA. Section 7, for example, prohibits the federal government from licensing new hydroelectric dam projects on the protected rivers. Licences and assistance for other water resource projects are permitted upstream or downstream or on a tributary of the protected river but only where the projects do not “invade” the river area or “unreasonably diminish” its values (sec. 1278). Federal agencies have an obligation to administer “[e]ach component of the national wild and scenic rivers system” so as to “protect and enhance the values which caused it to be included in said system” (sec. 1281). Furthermore, federal agencies must create management plans that address practices that are “necessary or desirable” to achieve the goals of the WSRA (sec. 1274(d)(1)).

Because the federal government shares certain powers with state governments, regulating the free flow of these rivers also requires sharing jurisdiction. In general, federal law controls quantity (i.e. the instream flow) through both the WSRA and the federal reserved rights doctrine, which provides that when certain federal lands are set aside there is an implicit requirement that they have sufficient water to fulfil the purposes for which they were established. The quantities of water are set either by adjudication or by agreement between the federal and state government.

Because water rights are adjudicated in state courts, however, the utility of a right will vary according to its date of priority relative to other existing state water rights. In the 1908 case establishing the reserved rights doctrine,² the U.S. Supreme Court held that although later water users had perfected their water rights under Montana state law, the water rights of Native Americans had priority since the reservation was established earlier in time. In most cases, the WSRA rights will be junior to most irrigation rights across the Western United States. Because the WSRA also requires the federal government to give just compensation to rights-holders if their water rights are taken (sec. 1284(b)), the WSRA mainly serves as a federal restriction limiting future water resource development in relatively intact systems.

2.1.2. Protecting and restoring flows in over-allocated systems

In basins that are highly modified and in dry climates where existing rights to use water often exceed available surface water supplies in normal precipitation

² *Winters v. United States*, 207 U.S. 564 (1908).

years, efforts to restore stream flow will often rely heavily on policy reform and legislation. First and foremost, legislation should recognize ecosystem uses (i.e. for fisheries, wildlife, recreation and water quality) alongside other uses. This involves setting up the relevant administrative process to allocate permits for such uses and also requires a policy decision on the relative priorities of the new environmental flow rights and existing rights.

By far the simplest way to ensure ecosystem health is to prioritize environmental flows above other uses. The obvious difficulty is that in some cases this may reduce or eliminate existing human uses. The Constitution of South Africa guarantees access to sufficient water and a safe environment as fundamental human rights, contingent on the availability of state resources. South Africa's 1998 Water Act reserves a minimum quantity of water for both human and ecological needs before allocation to other uses (including existing uses established under the 1956 Water Act). In the implementation of the human needs portion of the act, the government now provides a minimal "lifeline" of free water (the "social reserve"), equivalent to half of the minimum standard established by the World Health Organization.

Implementation of the minimum quantity for ecological needs (the "ecological reserve") has awaited the formation of catchment management authorities and the preparation of catchment strategies which include studies of environmental flow requirements. In 15 out of 19 water management areas in the country, the demand from all uses – that is, existing uses plus the expected levels for the social or ecological reserve – exceeds water availability, and the reserve is effectively not being met (Pollard *et al.*, 2007). Commentators suggest that the likelihood of full implementation of the ecological reserve is limited, with some experts acknowledging that as with other rights-based approaches the implementation of the reserve system will be subject to "progressive realization" (du Toit, 2007; Quinn and Marriott, 2006). In 2007, comprehensive reserve determinations commenced in four priority catchments (DWAF, 2007a). The challenge of actually enforcing such determinations against existing uses lies ahead.

The European Union's Water Framework Directive (No. 2000/60/EC) also addresses environmental flows. The directive calls for all states to achieve "good ecological status" in all water bodies by 2015. It does not posit environmental flows as an objective *per se* but rather as a means of achieving the "good ecological status" referred to in the legislation (Acreman and Littlejohn, 2007). There are provisions for exceptions in case of water bodies

declared to be heavily modified or for which the costs of compliance are disproportionately high. It remains to be seen how successful this approach will be. In the United Kingdom, initial assessments by environmental flow specialists suggest that compliance with the directive will require major modification of existing water use (Acreman and Littlejohn, 2007). Indeed, using existing methods and data, an initial assessment by the government was unable to even quantify the cutbacks in existing water uses that would be necessary to ensure sufficient instream flows to meet good ecological status (DEFRA, 2007).

In the Western United States, a number of states have passed legislation to establish instream flow as an authorized beneficial use and to allow state agencies to apply for minimum stream flow levels. Unlike the case of South Africa or Europe, however, these instream flow levels are not prioritized relative to existing water uses. Although diversions for irrigation severely curtail flows and result in poor ecological condition, the sociopolitical climate in the agrarian west made any attempt to effectively expropriate existing water rights for instream use a losing proposition. For example, under the U.S. State of Oregon's 1987 Instream Water Rights Act, minimum flows established by state agencies are full-fledged water rights but carry priority dates based on their establishment. They therefore do not serve to restore stream flow but rather serve only to prevent additional allocations when existing rights and instream rights fully account for available streamflow. On the other hand, the 1987 Act made provision for the conversion of existing out-of-stream water rights to instream rights through purchase, lease, donation and conservation. The Act in effect created a market for reallocating existing rights to instream rights with the key proviso that there be no loss of priority when the change to instream was made.

2.1.3. Restoring flows through species protection

An alternative to protecting or restoring rivers or flows directly is to place legal protections on the species that depend on water and flows for their habitat needs. In the United States, the Endangered Species Act of 1973 prohibits federal agencies from authorizing, funding or carrying out actions that would destroy or adversely modify habitat designated as critical for endangered species. Private groups that may "take" species through habitat degradation are also potentially at risk of sanctions under the act. Just as a land owner could be required to halt land development for fear of impacts on an

endangered rodent, so could a water right holder be forbidden to divert or use water should such water use impair habitat for an endangered fish.

Perhaps the most illustrative case is the Pacific Northwest salmon, a species found in California, Idaho, Montana, Oregon and Washington in the United States. Since the early 1990s a number of federal agencies involved in hydropower or storage reservoirs for irrigation have been trying to reduce or mitigate their impact on salmon habitats. For example, the Bonneville Power Administration, which produces power on the Columbia River, spares water for the benefit of salmon and funds a Fish, Wildlife and Environment Program that spends more than US\$ 150 million a year to improve conditions for Pacific Northwest salmon.

2.2. Conjunctive management

Conjunctive management is another way to regulate the whole water cycle, by considering surface water and groundwater as parts of the same hydrological system. Conjunctive management recognizes that a unit of water that recharges the aquifer, a unit of water in the aquifer and a unit of water that discharges from the aquifer back into stream flow actually represent only one unit of water. True conjunctive management should manage surface waters both upstream and downstream from the aquifer whilst regulating groundwater pumping. It should also consider aquifers as recipients of pollutants and take into account the resulting impacts on the quality of water withdrawn or discharged for human and ecosystem uses.

Conjunctive management has been adopted in Australia, Canada, Israel, South Africa and some states in the United States (UDWR, 2005). Implementation has not been widespread, in part because conjunctive management requires a strong legal system and well-functioning institutional arrangements and in part because many countries lack sufficient information about the linkages between surface water and groundwater. Precise data is needed to accurately project how different management actions will affect hydrological function and water availability. Conjunctive management is also a comparatively recent approach.

Essential legal changes to facilitate conjunctive management fall into two principal areas: water rights and institutional arrangements. In both cases, the key objective is legal certainty. Before agreeing to implement a conjunctive

management system, surface water users and groundwater users must be assured that their rights and their investments will be protected.

Water rights. The legal framework should establish secure, well-defined water rights to use and to store specific amounts of surface water and groundwater (Blomquist *et al.*, 2001). Water rights in a conjunctive management system affect incentives: the more defined the water rights, the more incentive rights-holders will have to store water and vice versa. Water rights under a conjunctive management system take the form of licences or permits that specify a certain allocation of water and explicitly state that they are for interconnected uses. It is also important to recognize the potential for the rights of third parties to be impaired by the implementation of a conjunctive management system (Foley-Gannon, 2000). In the absence of clearly defined rights, legal challenges can prevent or delay implementation, which can be costly (Foley-Gannon, 2000).

Institutional arrangements: Conjunctive management projects often involve multiple organizations or public-private partnerships (Blomquist *et al.*, 2001). This is due in part to prior allocation of authority over surface water and groundwater to various agencies, and also to the often great distances between surface waters, aquifers and downstream discharge zones. This complexity raises transaction costs. Establishing coordinating authorities or associations – water banks, water districts or other special agencies – may lower costs and also pool the risks associated with storing and recovering water (Blomquist *et al.*, 2001).

Conjunctive management arrangements need not take one form (e.g. centralized versus decentralized), but whatever form is adopted, the legislation should clearly outline the scope of agency control and administration. Local entities or agencies should have specific authority to engage in and participate in conjunctive management programmes and to enter into conjunctive management agreements. Legislation should also specify the scope of agency control over stored water. Agencies should be authorized to define rights to native water supplies (the naturally occurring groundwater) and to prioritize rights to available space, to protect recharge areas and to monitor extractions (Foley-Gannon, 2000).

Legislation may also define the extent of agency responsibility for protecting water quality and regulating the export of water (Foley-Gannon, 2000). Legislation may also require agencies to adopt water management plans, which

investigate the hydrology of a given water basin, related water quality, supply and demand issues and existing water rights.

2.2.1. Australia

Australia has created perhaps the most comprehensive national plan for conjunctive management. Known as the National Water Initiative (NWI), the plan was signed by the Commonwealth Government of Australia and the governments of Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia and Western Australia. Amongst the objectives of the plan are to create a “nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes by [recognizing] the connectivity between surface and groundwater resources and connected systems managed as a single resource” (NWI, 2004).

Australia has set forth four principles for conjunctive management: (1) physically connected waters should be managed as one; (2) water is assumed to be connected until proven otherwise; (3) all water users – groundwater and surface water – are to be treated equally; (4) and jurisdictional boundaries should not prevent management actions (Fullagar, 2004).

Amongst other features of the plan, states are encouraged to create a single licensing system to improve trade by assuring rights-holders that their rights are secure. Another important element of the plan is the need to coordinate surface water and groundwater use. The plan recognizes that when restrictions are placed on allocations from surface water, water users will turn to groundwater to fulfil their water needs. Thus, states are encouraged to implement “coordinated embargoes”, i.e. concomitant restrictions on groundwater use.

Each state or territory is charged with either adopting a legal framework in accordance with the requirements of the NWI or updating any existing legislation that is not in line with those requirements. For example, New South Wales may have to review its Water Management Act of 2000 as it allows water management plans to manage surface water and groundwater separately. Although state policy is to manage water in an integrated way through linkages between plans, many of the links are absent. The Murray-

Darling Basin Groundwater plans, for instance, do not address surface water even though groundwater has an impact on surface water flows.

2.2.2. United States of America

Several states in the United States have enacted conjunctive management laws or programmes of various sorts. These states tend to be in the West and have prior appropriation systems or dual systems of prior appropriation and riparian rights. The existing conjunctive management regimes fall into three general categories: states that manage their groundwater and surface water separately (even if they integrate management in certain districts); states that manage water in two separate systems with integrated permit reviews (i.e. permits are reviewed for their effects on both surface water and groundwater); and states that manage both types of water together, with no legal distinction between them (Tellman, 1996).

California manages its surface water and groundwater in two separate systems, although it encourages conjunctive water management through certain projects and funding. Surface water rights are better defined than groundwater rights, which have developed over time and mostly through judicial decisions and some agency decisions, with little standardization throughout the state. California generally follows the correlative rights doctrine for groundwater management, which means that overlying land owners share an equal right to water and shoulder an equal burden in times of shortage. These rights, unlike other water rights in the Western United States, are not dependent upon use (i.e. they are not forfeited in case of non-use).

Conjunctive management in California is undertaken at the local level by basin organizations driven by local conditions (Blomquist *et al.*, 2001). Because of this decentralized approach, and because the groundwater rights in California are not well defined, users may have little legal assurance that they will be able to recover later the water they store now (Blomquist *et al.*, 2001). Nonetheless, despite the obvious weaknesses, conjunctive management projects continue to be adopted in California (Blomquist *et al.*, 2001).

In the last few years, California's Department of Water Resources has taken additional steps to encourage conjunctive management through its Conjunctive Management Program. The associated water plan has three components: first, when surplus surface water is available, use it to recharge groundwater; second, when surface water is scarce, use the stored

groundwater; and third, create monitoring and evaluation programmes to “allow water managers to respond to changes in groundwater, surface water, and environmental conditions that could potentially violate management objectives or harm other users” (DWR, 2005). In addition, the water plan intends to improve water quality, reduce groundwater overdrafts and reduce salt water intrusion along coastal areas.

Colorado, by contrast, uses a prior appropriation system for both surface water and groundwater rights. Because the latter are often junior to the former, most of the groundwater rights cannot be used. This is because pumping would lower the stream flow of the surface water, thereby disrupting senior use rights (Blomquist *et al.*, 2001). Through the state’s Conjunctive Management Program, groundwater users can obtain water rights without interfering with the senior surface water rights.

The most commonly used method of conjunctive management in Colorado is “stream augmentation” (Blomquist *et al.*, 2001). Groundwater users acquire surface water, which they give to the State Engineer, who releases the water when the surface water users need it. The amount of water that groundwater users must provide to the State Engineer depends on the amount pumped by their wells. For example, in the Arkansas River Basin, where the well water is used to supplement surface water, the groundwater user need only replace 30 percent of the water pumped. By comparison, if the well water is used for sprinkler irrigation, the groundwater user must replace 7 percent of the pumped water (Blomquist *et al.*, 2001).

Colorado has a well-established water rights system, and water rights priorities are generally identified. Even so, complying with the rules for conjunctive management can be difficult because of the costs and risks involved. For this reason a number of organizations have been established to help administer the system. They help water users, especially small irrigators, deal with compliance and pool their risk (Blomquist *et al.*, 2001).

Utah is another example of conjunctive management in the United States. Most of the water resources in the state are closed or restricted to new appropriations, with only 26 percent of the water resources open to further development (UDWR, 2005). Since the least expensive sources of water have already been developed, conjunctive management has grown in importance. The state began experimenting with conjunctive management in the 1930s and today three conjunctive management projects are in operation (UDWR, 2005).

Utah's system relies on a variety of permits. For example, users intending to recharge groundwater must have a recharge permit and must hold a valid water permit for the water to be recharged. Any user intending to recover stored water must obtain a recovery permit. The recovery permit holder does not need to be the same as the recharge permit holder, so long as the recoverer has a written agreement with the recharger to recover and use the stored water. Additional permits include those for monitoring wells and injection and recovery wells. Projects that intend to divert water from a stream must obtain a stream alteration permit, and wells that will recharge groundwater must have permits for injections. The injected water must be of equal or better quality than the receiving water.

In addition to the permitting requirements, Utah requires water users to consult with local governments, in part because local laws, such as zoning laws, might affect conjunctive management programmes. In such cases, conjunctive management projects may need special use permits or special construction permits.

2.3. Exempt uses

As described earlier, when an upstream land manager harvests rainwater or alters land use so as to increase evapotranspiration, the activity falls outside government regulations in most jurisdictions. Although the idea that certain uses are exempt from regulation may date back to Roman times it may by time for reconsideration.

Viewed purely in hydrological terms, if the entire system were well managed then any user of water – whether capturing precipitation, withdrawing groundwater or diverting surface water – would need to obtain a permit, just as for any other use. Existing regulations regarding the allocation and prioritization of uses would then determine if the permit should be granted and if so, how pre-existing downstream users would be protected from any potential harm from the additional use.

Although an attractive notion from a hydrological management standpoint, this may not be economically practical. The notion that precipitation and waters flowing across private land and small domestic wells should be considered either the property of the land owner or outside the scope of regulation likely rested on the view that the costs of regulating and managing these resources were high compared to the benefits. As water has become

scarce over time, the costs of not regulating such uses may look increasingly high. Similarly, as understanding of hydrology has increased and technologies for remote sensing, hydrological monitoring and modelling have improved, the costs of developing and enforcing regulations on smaller users have fallen.

For these reasons, in certain places and under certain circumstances it is not unusual to see governments either reducing the types and amounts of exempt uses or moving them into a formal permitting system. In the Walla Walla basin of the U.S. State of Washington, for example, exempted uses of groundwater included water for domestic, in-home use and for up to 0.2 hectares of outdoor irrigation. Following rapid growth of residential housing on top of a shallow alluvial aquifer that feeds a downstream fishery listed under the Endangered Species Act, the state enacted regulations in 2007 to limit the exempt uses to in-home use and to require purchase of an offset for any outdoor watering using groundwater.

It is worth noting here that an argument can always be made and will have strong socio-political backing that certain uses should always be exempted, i.e. for drinking water and domestic purposes. However, at least in developed countries, the pressure on water resources from expansion of residential and urban areas can be significant. Most water used in these households is not to meet basic needs and, therefore, may be fair game for new regulations that explicitly recognize, quantify and permit such uses, subject to existing management plans and water availability.

With regard to rainwater, most public policy approaches seem to consider it a “new” source of water. Instead of integrating rainwater harvesting into regulations governing groundwater and surface water, most policy-makers simply pursue economic incentives to promote the technique. Thus, the City of Santa Fe in the U.S. State of New Mexico has set forth three classes of residences and commercial buildings, each requiring a different level of investment in rainwater harvesting. Myriad other tax credit, grants and other market-based instruments are also used to subsidize the instalment of rainwater systems.

Finally, with regard to land management, most regulatory systems do not incorporate downstream considerations, as already noted. The rationale for not including such watershed or hydrological services in a formal regulatory framework is mainly due to the difficulty of evaluating the impacts of land uses and the relative costs. For example, it would be difficult to assess on an

annual basis the change in water yield (or baseflow or sediment) associated with a change in land management on a property that included forest, a residence and a number of crop types. It would also be difficult to track any impacts for one property versus all the other properties in the watershed, each with their own location, sub-surface geology, distance to surface waters, etc. The link between cause and effect is not only difficult to predict but also hard to monitor and verify *ex post facto*.

Regulatory efforts have mainly consisted of contractual arrangements for performance, i.e. for the land manager's adoption of a certain set of management practices. Other initiatives focus on positive and negative incentives associated with different land uses. Some other regulatory examples are explored in the next section.

III. CHANGING INCENTIVES THROUGH REGULATION

There are many ways in which regulation can affect the incentives facing land and water users with the goal of managing water in a more integrated fashion. The many tools, instruments and systems can be grouped into four standard categories employed by economists:

- project investments;
- command and control regulation;
- market-based instruments;
- cap and trade systems.

Each of these will now be addressed in turn and illustrated with specific examples.

3.1. Project investments

Project investments refers to the appropriation of government funds to undertake specific on-the-ground projects, e.g. building a dam or re-engineering a stream system. These funds represent direct centralized provision of public goods. This is a well-known and longstanding approach to water resources development, although future project investments may need to shift to ecosystem restoration. As seen below, there will be cases where regulatory tools do not sufficiently balance human and ecosystem uses: they may limit further ecosystem degradation but do not achieve restoration. The government may therefore need to consider using public funds to buy water

use and pollution permits back from users in order to achieve ecosystem restoration goals.

3.2. Command and control: establishing limits on use and pollution

Command and control approaches consist of regulations placed on water users (users of water quantity and quality) which either set the level of resource use or pollution or require users to employ a particular technology in connection with their water use. For example, the state may set the level of water pollution that a point source may discharge or may mandate a particular pollution control technology. The command and control approach implicitly recognizes that the use or pollution is a problem, and that regulations are needed and are likely more cost effective than the status quo.

Technology-based standards specify the methods and equipment that must be used to comply with the regulations. Performance-based standards set uniform control targets for all regulated users but, unlike with technology-based standards, the users are given some choice over how the target is actually met. This tends to minimize the costs of compliance.

Overall, the advantage of command and control approaches is that they directly address excessive levels of resource use or pollution. The disadvantage is that they fail to take account of variations in the opportunity costs of resource use and pollution abatement across users. Requiring all users to adopt a specific pollution technology or use only so much water does not necessarily lead to efficient outcomes in terms of resource allocation.

3.2.1. Land use zoning

An example of a command and control tool in land management is zoning, whereby only certain activities are allowed, based on land characteristics, soil suitability or other measures. Zoning in rural areas typically distinguishes between residential zones and zones for different rural production activities such as agriculture, ranching, forestry and wildlife. Generally, zoning has not adequately accounted for the off-site impacts of downstream hydrological services. For example, the value of groundwater recharge areas is typically not taken into account when urban expansion into rural areas is considered. Soil quality is often considered in zoning areas for agriculture, but not the impacts on runoff, recharge and downstream water quality.

Box 9.2 - Environmental Flow Targets in Switzerland

Amongst the purposes of Switzerland's Federal Law on Protection of Water (1991) are to protect water for the "natural functioning of the hydrological cycle" (art. 1(h)). The law also sets out requirements for maintaining a minimum instream flow. It requires permits for any water withdrawals that exceed normal consumption from "permanently flowing watercourses", as well as for groundwater or lake withdrawals if those withdrawals "substantially affect" the flow (art. 29). Permits will be granted if the requirements of the law are met, if the withdrawal does not reduce the rate of flow Q_{347} ³ by more than 20 percent or if the total amount of withdrawal is not more than 1 000 litres per second (art. 30).

The act specifies the minimum residual flow for water bodies, i.e. the "rate of flow of a watercourse which remains after one or several withdrawals of water" (art. 4). These minimum flow requirements may be increased in certain circumstances, such as where water quality cannot be maintained with the water withdrawals and wastewater discharges (art. 31(2)(a)) or where the water depth that fish need for free movement cannot be maintained (art. 31(2)(d)).

When the authorities decide that the minimum residual water flow needs to be increased, they must weigh and balance certain interests in favour of and against demands for water withdrawals. Factors in favour include the public interests that may be served and economic interests of the potential withdrawer. The factors against withdrawal include the significance water has as part of the landscape and "as a biotope for the fauna and flora dependent on it"; the need to maintain the rate of flow for water quality requirements; and the water needs of agricultural irrigation (art. 33). Users wishing to withdraw water must prepare a report that addresses the consequences of the withdrawal, calculates the various flow rates, elaborates the interests the withdrawal will serve and the interests that may be impaired and identifies the measures that could prevent the impairment (art. 33).

³ Q_{347} refers to the rate that is reached or exceeded an average of 347 days each year (averaged over ten years) and which damming, withdrawal and water supply do not substantially affect (art. 4).

3.2.2. Environmental flow targets

A command and control approach can also be used for environmental flows, either by specifying the method that must be used to set environmental flow targets or actually prescribing the level of flows that must be achieved. Switzerland's water protection law, for example, requires strict calculations before permitting of new water uses so as to protect minimum streamflows (see Box 9.2). Similarly, the European Water Framework Directive sets "good ecological status" as the performance bar for environmental flows, as already noted. Since many streams and rivers will fail this test, the European Union is using this command and control approach as a tool for restoring environmental flows.

There are a variety of methods available for determining environmental flow requirements in a given system: a recent review found 207 methods across 44 countries (Tharme, 2003). Table 9.1 illustrates the system in South Africa, where existing flow regimes and ecological conditions are classified from natural to poor.

Table 9.1 - Ecological Management Classes in South Africa

Class	Flow Regime	Ecological Condition
A (natural)	Close to natural	Negligible modification of habitat and biota.
B (good)	Largely natural; few modifications	Ecosystem in good state; biota largely intact.
C (fair)	Moderately modified	Loss of sensitive species; some populations in decline; tolerant or opportunistic species may increase.
D (poor)	Largely modified	Habitat diversity and availability in decline; tolerant species present; population dynamics disrupted.

Source: Postel and Richter, 2003.

The decision about the desired flow regime and ecological condition is ultimately a decision for society to make and not just a technical one, as

altering water use carries with it a series of social, economic and environmental costs, benefits and risks. Legislation requiring all streams and rivers to attain, for example, Class B (in Table 9.1) may seem the right decision to some but arbitrary to others. It will also result in widely varying costs on the part of those having to meet the required environmental flow regime.

3.2.3. Caps on water use and pollution

An alternative to setting environmental flows is to set limits on water use or pollution. In developed countries, as water resources have become over-allocated, states have often found it useful to “close” basins. By not permitting additional uses of water, the overall resource use is capped. As detailed in Box 9.3, this can be done at a very large scale, such as with the cap on water use set in the Murray-Darling Basin in Australia. Environmental flows were not a factor in setting the cap, whereas in the U.S. State of Oregon instream water rights are included in the calculations of whether a basin should be closed to further appropriation.

Box 9.3 - Murray-Darling Basin Cap in Australia

In June 1993, the Murray-Darling Basin Ministerial Council directed that a study be undertaken on the issue of altered flows and their consequences for the rivers of the Murray-Darling Basin (MDBC, 2003). This led to an audit of water use, which confirmed increasing levels of diversions and associated declines in river health. In response, the Council introduced an interim cap on water diversions in the basin in 1995 and a permanent cap in 1997. In imposing the cap, the Council essentially balanced the social and economic benefits to be derived from development of the basin’s water resources and the water needs of the riverine ecosystem.

In 2000, the Council commissioned a comprehensive review of the operation of the cap, which concluded that:

- the cap has supported the Council’s aim of achieving the ecological sustainability of the basin’s river systems;
- although the cap does not necessarily provide for a sustainable basin ecosystem, it has been an essential first step toward this end;
- without the cap there would have been a significantly increased risk of increased environmental degradation of the river system of the basin.

Caps on pollution discharge are another important tool in regulating environmental quality in waterways. In the United States, the Clean Water Act has been instrumental at limiting pollution and reducing pollution levels. Under the act, waterways must not exceed certain nutrient levels and states must develop plans for remediating waterways back to established levels.

Ideally, such caps would be integrated. For example, closing a basin to surface water withdrawals but continuing to issue groundwater permits makes little sense if groundwater and surface water are hydraulically connected. Equally, since flow in a river is an important factor in nutrient concentrations, there is also a connection to be made between resource and pollution caps. But technical challenges remain. For example, the Government of the United Kingdom has been able to calculate the costs of complying with certain of the nutrient requirements of the European Water Framework Directive but has been unable to understand the flow and quality nexus or to calculate the cost of required flow levels (Acreman and Littlejohn, 2007).

3.3. Market-based instruments

Unlike command and control mechanisms, market-based instruments do not prescribe what water users may or may not do, but rather affect the costs and benefits that users face in the marketplace. In this way market-based instruments can be used to steer private behaviour towards social objectives. The classic example is the polluter pays principle, whereby a tax is placed upon polluters. If the tax is formulated to reflect the marginal external costs of the pollution, then society will in effect internalize these external costs and supply and demand will adjust from market levels to levels that produce an efficient allocation of societal resources. Similarly, if land managers or water users are engaged in practices that have negative outcomes for ecosystems, then government may offer a subsidy or payment to reduce water use or increase water quality.

One advantage of market-based instruments is that they make the opportunity cost of pollution (or water use) clear to the user. In theory, then, the user will work to reduce his or her pollution to the point that the cost of another unit of pollution reduction is equal to the tax on the pollutant. Users will also likely explore all the different means at their disposal to limit their effluent or emission. Another advantage of a tax or payment system is that the tax is set by the central authority and therefore there is no uncertainty (at least within the current tax period) as to the price of pollution.

One problem is that technical information is needed to set the amount of the tax or payment to achieve an efficient level of pollution. There may also be a continuing need to adapt the tax level over time so as to move towards the pollution target. More importantly, there remains no disincentive for those polluters that can afford to pay the tax to continue polluting.

3.3.1. Evapotranspiration taxes and subsidies

South Africa has for sometime been formulating and now experimenting with a tax for any activity deemed a stream flow reduction activity (SFRA). The Water Act of 1998 specifies that afforestation for commercial purposes can be classed as an SFRA and therefore subject to licensing as a water use and to the assessment of charges (Shine *et al.*, 2000).

A tax on evapotranspiration and water use has two impacts. First, it raises the cost to the land manager of engaging in activities that will lower streamflow downstream. All things being equal, this reduces the activity's profitability and may dampen further investment in the activity. Second, the tax provides a source of funds that can be used to offset the impacts of the activity that is affecting streamflow. Unfortunately, independent reports from South Africa indicate that current charges are not yet offsetting water use by plantation forests. Still, the South African legislation provides a useful illustration of how changes in land use that lead to higher evapotranspiration rates can be included in water legislation.

3.3.2. Payments for watershed services

South Africa has a Working for Water Programme which subsidizes efforts to improve land management with a view to improving downstream hydrological services. The main concern is enhancing water supplies, particularly during dry periods. Amongst other activities, local communities (in particular contract labour sourced from previously disadvantaged groups) are paid to remove alien invasive species that have been shown to cause higher water losses. From 1995 to the 2002/2003 budget year, the government spent the equivalent of US\$ 300 million and cleared 1.25 million hectares of alien invasive species (Marais *et al.*, 2004).

By comparison, the United States Conservation Reserve Program (CRP) originated largely as a means of tackling non-point source water pollution in agriculture. The CRP is part of the U.S. Farm Bill and provides a range of

subsidies to farmers that idle land and undertake conservation measures. CRP represents perhaps the largest national effort to subsidize watershed services. In 2006, the federal government spent US\$ 1.9 billion on the programme and from 1986 to 1996 some 14.5 million hectares had been enrolled in the programme with total outlays of US\$ 32 billion (FSA, 2007).

Costa Rica and Mexico also have national payment programmes that intend (at least in part) to improve downstream hydrological services. In Costa Rica, the 1996 Forestry Law (No. 7575) recognized the concept of environmental (or ecosystem) services provided by forests, including carbon fixation and sequestration, biodiversity conservation, scenic beauty and watershed protection. The Payment for Environmental Services programme that emerged pays land owners to protect and manage their forests for the provision of these services. The law also makes clear that no forest may be harvested or cleared without the proper government permission.

Mexico's programme, worth US\$ 20 million per year, targets the hydrological benefits of maintaining existing high altitude cloud forest areas (Muñoz-Piña *et al.*, 2008). The funds come from the fees paid annually to the National Water Commission by large non-agricultural water users. With payments of around US\$ 40/hectare/yr, the programme protects over 300 000 hectares under five-year contractual arrangements.

It is important to note that these payment (or subsidy programmes) are distinct from voluntary contractual arrangements whereby a downstream water user directly pays an upstream land manager to undertake improved practices (or refrain from practices) that will negatively affect downstream services. In such cases the beneficiary pays for the benefit to be received, and except for contract rules, no legislation is required. By contrast, because the national programmes just reviewed are government-run, they require legislation to secure funding and create institutions (Aylward, 2007).

3.3.3. Irrigation water pricing and demand management

Historically, many large irrigation schemes have failed to pay back their construction costs. Even today many such systems do not cover their running costs and are in effect subsidized by public funds. The price for the delivered water is often set according to a fixed allocation and not the amount of water farmers receive. For efficient allocation of water, water should be priced based on the water used, and a progressive tariff should be considered for

allocations beyond the base level. An example comes from the North Unit Irrigation District in the U.S. State of Oregon, where farmers pay a fixed price for a base allotment and then pay for additional water on a volumetric basis. Farmers in this district typically turn out half as much water as farmers in other districts in Central Oregon, which instead assess fixed charges based on the land area irrigated.

Where upstream watershed protection is important, additional charges to support beneficial land uses should be considered. For new irrigation schemes full cost pricing should be applied, including any costs to mitigate environmental impacts. The goals of the pricing systems should be made explicit: they may be targeted towards cost recovery, demand management or meeting social or environmental objectives.

3.3.4. Payments for agricultural water conservation

An important source of water is the conservation of existing supplies. There are substantial savings to be gained from improvements in agricultural (as well as municipal and industrial) systems around the world. Direct payments to farmers and irrigation districts undertaking piping, lining and on-farm conservation activities are increasingly proving effective at generating saved water. Irrigated agriculture is estimated to be only about 40 percent efficient on average, with the remaining 60 percent lost through leaky or unlined canals, over-watering of crops and inefficient technology. Because a portion of this lost water typically returns to a waterway or recharges groundwater and is subsequently available for uses downstream, there is the potential for conservation to increase overall productivity of water use (although this will be site-specific).

The United States Department of the Interior operates an annual challenge grant programme – *Water 2025: Preventing Crisis and Conflict in the West* – to provide funds for collaborative conservation. In 2005, the majority of the US\$ 10 million went to fund agricultural water conservation projects in the western states. Water from these projects is typically available for other water users in order of priority. However, a number of states provide ecosystem restoration groups with incentives for investment in these projects by allowing the conserved water to be protected for instream purposes. Through its Conserved Water Program, the State of Oregon also allows private investors in a project to capture up to 75 percent of the conserved water and dedicate it to new uses, once 25 percent has been dedicated to instream flows.

3.4. Cap and trade systems

Alongside market instruments like taxes and subsidies are more sophisticated efforts to harness the power of economic incentives. Effective regulation of water use and pollution can be accomplished through the creation of regulated markets for ecosystem services. So-called “cap and trade” systems can be a useful and efficient method for limiting resource extraction or pollution. As described below, such trading systems are developing across the spectrum of water resources management.

A cap and trade system sets an aggregate rather than individual cap on pollution (or resource use). Tradeable allowances take the form of individual quota shares of the aggregate cap. For example, a system of marketable pollution permits requires three steps:

- determining an overall maximum level of pollution (the cap);
- assigning available pollution permits to polluters; and
- allowing polluters to buy and sell pollution permits so long as the total pollution is equal to or less than the cap.

“Mitigation” or “offset” programmes represent a slight expansion of this type of permit system in that they allow third parties to enter the pollution credit market with activities that offset pollution and generate credits. The credits are then sold to polluters. Mitigation programmes require the same three steps, but the emphasis is typically on “no net loss”. This means that no overall increase in pollution is allowed: in effect all existing polluters are allocated permits to pollute equal to their current pollution and any new pollution needs to find credits to offset itself, to achieve no net loss.

Cap and trade systems function the same whether pollution or water use is being capped. For water use, of course, it is water rights and not pollution permits that are traded. Although cap and trade systems have as their primary objective holding pollution (or resource use) to a targeted level, once established they may also be used to lower the overall pollutant load or reduce overall resource use. Continuing with the pollution example, if third parties are allowed to purchase permits (or credits), then the price of permits will rise and the supply will be smaller, leading to lower pollution levels. By monetizing pollution, these systems allow for a market to emerge not only in pollution control but also in ecosystem restoration. This is because the existence of a market for permits and offsets makes it more likely that polluters and third-

party providers will search for low-cost solutions, which may include restoring degraded ecosystems.

The principal advantages of cap and trade systems are that they allow explicit setting of pollution (and resource use) targets and they reduce the cost of abatement. A related advantage is that they leave price-setting to the market – to buyers and sellers – and not to government officials. The disadvantage is that they leave buyers and sellers with price uncertainty, at least at the initiation of the programme. This can increase political resistance to such schemes by large institutional players and industry. The programmes can also be complex to administer since monitoring, tracking and reporting are required to ensure that the programme meets its targets and that the participants are following the rules. Still, these are largely start-up issues and based on current evidence, a well-designed cap and trade system, at least of pollution management, appears to be cost-effective (Freeman and Kolstad, 2007).

3.4.1. Surface water trading

One problem with a cap and trade system for water rights is that it effectively blocks prospective new water users from acquiring and using water. By contrast, allowing existing water right holders to sell, lease or donate their water rights to others creates a system where low value uses of water can move to higher value uses. If charges are low the water is effectively free and therefore the user is likely to use his or her allocation regardless of its contribution to economic output. Once the system allows the user to trade water rights, he or she can decide whether to use the allocation or trade it. Where the market allows other prospective users to communicate their need and demand for the water, then the user is more likely to choose the use that reflects what society as a whole would choose, i.e. the use with a higher economic value.

The ability to transfer water will lead to more productive use of water in its existing uses as well as provide a source of water to new economically vibrant uses. Such a system also provides a voluntary and financially rewarding way to carry out streamflow restoration where ecosystems are valued by local communities, without taking water from farmers through regulatory or bureaucratic means. As employed for environmental purposes, these approaches are perhaps best developed in Australia and the United States (Garrick *et al.*, 2008).

Perhaps the most ambitious scheme of this type comes from Australia where the federal government has appropriated US\$ 10 billion to restore the Murray-Darling Basin. Of this sum, US\$ 3 billion has been earmarked for recovering water for environmental flows – through purchase of water rights and through infrastructure improvements that result in water being saved. The money comes with new legislation which will allow the Australian Government to set the sustainable diversion limit for all surface water and groundwater resources of the basin.

In the United States in the State of Idaho, the Bell Rapids Irrigation District sold all of its 10 000 hectares to the state government (for US\$ 24 million), which will now lease the water for instream flow to the federal government for salmon and steelhead recovery. Similarly, in the Klamath Basin of California and Oregon, the federal government pays farmers not to pump groundwater so as to provide higher flows for salmon. Elsewhere in the Pacific Northwest, a growing number of NGOs use water leasing and transfers to restore tributary flows for fish, recreation and water quality under the Columbia Basin Water Transactions Program financed by the Bonneville Power Administration.

3.4.2. Groundwater trading

Cap and trade systems for groundwater place a limit on total groundwater withdrawals, distribute groundwater pumping credits and then allow trading of credits between users. In some systems credits are also issued for any additions made to aquifer storage, which provides incentives to invest in aquifer recharge. An active groundwater credit trading system is in place in the Edwards Aquifer in the U.S. State of Texas. Equally, a recharge credit system is being evaluated in Australia with the aim of improving the management of waterlogging and irrigation-induced salinity management in the Coleambally Irrigation Area.

3.4.3. Integrated trading

Another option is a trading system that takes into account both groundwater and surface water, i.e. with an integrated cap. In such a system, the downstream impact of new groundwater withdrawals would be offset by restoring streamflow or recharging aquifers. To ensure that consumptive use is capped, the denomination of the credits traded may need to be in consumptive use units, not units of diverted or withdrawn water. In 2002, the

State of Oregon developed such a cap and trade system for the Deschutes Basin, which has led to the development of markets for both temporary and permanent groundwater mitigation credits. Municipalities, developers and irrigators desiring to develop new groundwater rights must first acquire credits that are created through the retirement of existing surface water rights.

3.4.4. Water quality trading

A final example of changing behaviour through financial incentives is to allow water quality trading. This type of system has emerged in the United States. In 1990, Connecticut, New York, and the United States Environmental Protection Agency agreed on a plan to reduce nitrogen discharges into Long Island Sound by 58.5 percent between 2000 and 2015. Connecticut and New York incorporated the target into a total maximum daily load (TMDL) for nitrogen. To meet its commitment, Connecticut chose to implement a nitrogen credit trading system among point and non-point sources. In its first year of operation, the programme reduced nitrogen discharges by 15 000 pounds, or 50 percent of the target reduction (Aylward *et al.*, 2005).

Trading has also developed for other types of nutrients. For example, in Australia's Murray-Darling Basin, efforts are under way to develop markets for salinity trading. Under the basin's Salinity Debits and Credits Management Framework, states that acquire salinity credits by contributing to salinity-reducing projects may be allowed to increase salinity within agreed limits if they employ salinity debits. In the U.S. State of Oregon, planning is proceeding in the City of Portland to develop a storm water trading system. Developers would have a choice between providing their own on-site mitigation measures, buying credits from third parties or making payments to fund large storm water projects developed by the city.

Whereas water quantity trading between out-of-stream uses has a considerable history and is well developed, efforts to trade water for environmental purposes are still in their early stages and those for water quality are in their infancy. The few examples that exist are in developed countries. It remains to be seen whether there will be additional innovations in other watersheds and in other contexts in the future.

IV. CONCLUSIONS

Water legislation has traditionally been used to establish permit systems for water use and point source pollution and to regulate the development of water infrastructure. Given the poor state of freshwater resources in the world, new approaches are needed. Water legislation should strive to implement integrated water resources management and set the parameters for improved governance across the water cycle. Regulatory frameworks should promote sustainable water use, foster better land management practices and encourage water quality improvements. Institutions and rules should enable water users and land managers to continuously enhance the productivity of water use for human development and ecosystem protection.

Central to this mission will be the need to alter incentives facing water users so that they bear the true cost of their resource use or pollution. At the same time, flexibility is essential to take account of changes in the character and nature of water use, in order to make room for new and higher value uses. A range of regulatory approaches can lead to more flexible, low-cost and adaptive water management. Regulatory frameworks and systems should foster innovation, experimentation and expansion of successful approaches. Examples of improved governance of water resources should be shared widely to help all countries, especially less developed ones, avoid having to relearn the lessons of past failures.

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CONCEPTIONS OF WATER**Contents*

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This text has reviewed aspects of water management from a variety of perspectives. The overall theme has been one of integration: of legislation and science, of the national and international realms, of quantity and quality, of surface water and groundwater and of human and ecosystem uses. Increases in world population and in global water demand will heighten the need for holistic and integrated solutions to manage water resources sustainably for future generations.

The coming years will see accelerating globalization and an easier exchange of information across national and international boundaries. New scientific and regulatory questions will arise and are sure to attract scholarly interest. The preceding chapters examined a number of innovative approaches to managing water, and introduced several new conceptions of water and water-related services. A key theme of this text has been the importance of ecosystem uses of water, an idea that has been under-valued or absent from many scientific and regulatory approaches to date. This concluding chapter highlights three more conceptions of water and water-related services that may garner increasing attention as the twenty-first century unfolds: water as a commodity, water as a service and water as a human right.

I. WATER AS A COMMODITY

One issue sure to persist on the international agenda is whether water is a tradeable commodity subject to international trade law – essentially, whether water falls within the purview of the General Agreement on Trade and Tariffs (GATT) or other regional trade agreements. The debate will continue in part because the GATT, which regulates trade in goods, does not itself define what a “good” is.

Some commentators who argue that water is a “good” point to the fact that it is not specifically excluded as such from the GATT. Further, they point to its inclusion in tariff heading 22 January 1990 of the Harmonized Commodity Description and Coding System where water is classified as a beverage under the heading “Waters, including natural or artificial mineral and aerated waters ... ice and snow”. Other commentators imply that water is covered by the GATT as a “primary product” given that “product” is defined as “any product of farm, forest or fishing or any mineral, in its natural form or which has undergone some processing as is customarily required to prepare it for marketing in substantial volume in international trade” (Annex I; art. XVI).

The notion has been advanced that for water to be considered a tradeable good, it should have been altered somewhat from its natural state by human intervention, for example through some form of production process. Although this argument originates from a plausible premise, it is less clear what would qualify as human intervention and what process would amount to a change of water from its natural state.

A number of GATT provisions are relevant to the debate on water as a tradeable commodity. These include the two key GATT principles dealing with non-discrimination, i.e. most favoured nation and national treatment. The most favoured nation principle requires all members of the World Trade Organization (WTO) to grant each other equal treatment with respect to “like products” originating from or destined to the territories of other WTO members (art. I). The national treatment provision, on the other hand, requires that once “foreign” goods have entered a particular market, they must be treated in the same manner as locally produced or domestic goods (art. III).

In addition to this basic principle of non-discrimination, GATT, Article XI(1), could be relevant to water to the extent that it prohibits the quantitative restriction of imports or exports. Concerns have been raised about whether under Article XI governments would be barred from prohibiting bulk water transfers or would be barred at least from stopping such bulk transfers once they began (Gleick, 2002).

Article XX may also be relevant as it can be invoked to allow a member state to apply an export restriction if it is necessary, amongst other reasons, for the protection of animal and plant life and health or the conservation of “exhaustible natural resources”. Whether or not water is an exhaustible natural resource has also been the subject of debate, with some commentators arguing that it is not since it is reproduced through the natural water cycle. However, the WTO Appellate Body has interpreted the term “exhaustible natural resources” in the past to include salmon, clean air and sea turtles and it is therefore probable that water will be considered an exhaustible natural resource.

The Marrakech Agreement which established the WTO is also implicated in the debate. In the preamble to the agreement, countries recognized the importance of an “optimal use of the world’s resources in accordance with the objective of sustainable development, seeking both to protect and

preserve the environment”. One may read into this language the desire to ensure that water resources are managed and consumed in a manner that ensures long-term sustainability even if they are considered a tradeable product under the WTO.

II. WATER AS A SERVICE

The General Agreement on Trade in Services (GATS) covers all service sectors except air transport and those services “supplied in the exercise of government authority” (WTO, 2007). As such, the GATS may affect water management through the water supply, water treatment and sanitation sectors. However, the degree to which the GATS will affect public services (such as health and water services) is a subject of great debate amongst both critics and supporters of the agreement.

Under the GATS, WTO member countries, especially developing countries, are under pressure to liberalize their service sectors and to open up markets to greater competition from private providers including multinational corporations. However, GATS commitments may only be reversed in certain limited circumstances or may require the payment of compensation to other member countries. This could have implications for water management in that a nation wishing to regain control of the provision of water services from a private sector business may find that a costly choice (PSIRU, 2006). In a bid to allay fears that WTO members, especially developing countries, were being compelled to liberalize their water services sector, the WTO Secretariat has stated that under GATS, members are free to pursue different options in this regard, including (i) maintaining a public or private monopoly, (ii) opening the water market to domestic competition, (iii) opening the water market to foreign competition without making a GATS commitment, and (iv) making a GATS commitment to grant foreign companies the right to supply water services in addition to national service suppliers (WTO, 2009).

2.1. Environmental services

The GATS includes 12 categories of services in its list of classifications, which may be changed through agreement or negotiation. Recent attempts to add water under the GATS have sought to include it as an environmental service. For instance, the United States submitted a paper that focused on pollution control and waste management services, and although it did not specifically mention water supply, it did suggest that all environmental

sectors should be liberalized, including those sectors that are “related to the core environmental services sectors” (PSIRU, 2006). WTO members have agreed to and have encouraged the liberalization of environmental services, which fall under GATS Classification 6 and include sewerage, refuse disposal, sanitation and “other” (which can include nature and landscape protection and other environmental protection services). The European Community (EC) proposed including water in the environmental services definition, suggesting the addition of “water for human use and waste water management” to the environmental services category (PSIRU, 2006). However, what constitutes an “environmental service” is not yet known: as a case in point, there is debate over whether drinking water provision is an environmental service.

To date, WTO members’ support for adding water for human uses to the list of services governed by the GATS has been weak whilst public outcry has been strong. In subsequent requests, the EC left out water for human uses (the collection, purification and distribution of water) but continued to focus on sanitation and sewerage services (Varghese, 2006). This is another example of the uncertainty surrounding the extent of the GATS’ reach over water resources management and services, which will depend on future rounds of negotiations. It remains, for some groups, a contentious topic.

2.2. Other water-related services

Although water for human uses has been left out of negotiations and requests in recent years, the GATS does affect other water-related services. In particular, it may limit the actions governments can take to regulate water use, allocate water or establish licensing schemes for water abstraction, service provision or effluent discharge.

Ownership of water resources is a key issue. As noted in earlier chapters, most countries choose to maintain ownership over the resource but allow property rights in the use of the water (usufructuary rights). Some GATS opponents have contended that by agreeing to make liberalization commitments under the GATS, countries’ sovereignty will be eroded and their regulatory role circumscribed. Although this argument has also been advanced by WTO members with regard to commitments under other WTO agreements, it has been most pronounced under GATS. As the World Wide Fund for Nature (WWF) and the Centre for International Environmental Law have stated, “[i]f access rights to water are granted in such a way as to

embed the right to take for long periods, with compensation payable for any policy changes, the regulatory entities may find themselves constrained, at least financially, in putting in place regulatory changes” (WWF and CIEL, 2003). Put simply, if the government grants water rights to service providers, depending on the circumstances it may need to compensate these providers if it later withdraws or reduces the rights that were granted. Here, the “reversibility” of a GATS commitment is critical. WWF-CIEL concluded that regulators will have to make careful water allocation decisions, as they would likely have difficulties subsequently in altering the legal frameworks.

The issue of a government’s freedom to issue licences may raise similar concerns. Licences are a means to grant access to water for uses such as industry, irrigation, livestock watering, water service provision or wastewater discharge. Because licences play an essential role in the management of water resources, limitations set by GATS could potentially affect water conservation efforts. The market access provision specifically prohibits measures that limit the number of service suppliers, the total value of service transactions, the total number of service operations or the quantity of service output, as well as measures that restrict the types of legal entities that may supply a service or that limit the participation of foreign capital (art. XVI(a)-(f)). Hypothetically, if a nation entered into a commitment that involved water abstractions and later established a national policy that contained or resulted in quantitative limitations on the number of licences that could be granted for abstraction, the policy might come into conflict with the GATS rule. On the other hand, it is not yet entirely clear whether and to what extent the market access rules of the GATS would apply; therefore, whether the rules would inhibit the use of licences as a regulatory tool remains an open question.

III. WATER AS A HUMAN RIGHT

Water was once perceived as being abundant and freely available to all, like air. More recently, this perception has ceded to the recognition that access to water is not a given for all people, and challenges such as pollution and climate change are increasing water scarcity. More and more, water is being discussed in human rights terms – as a right in itself and as an issue calling for a human rights-based approach.

3.1. Existence of the right

Water is not explicitly mentioned in the International Bill of Rights,¹ although it is necessary and integral to a number of human rights recognized therein. According to the United Nations Committee on Economic, Social and Cultural Rights (CESCR), the right to water is derived from two articles of the International Covenant on Economic, Social and Cultural Rights (ICESCR), Article 11 (right to an adequate standard of living, including food, clothing and housing) and Article 12 (right to highest attainable standard of health).

The lack of an explicit mention of a right to water has triggered some discussion on whether there is such a right or whether it is more correctly seen as instrumental to other rights. However, access to water is explicitly mentioned in the 1979 Convention on the Elimination of All Forms of Discrimination Against Women (with respect to rural women), the 1989 Convention on the Rights of the Child (regarding clean drinking water for the right to health), the 2006 Convention on the Rights of Persons with Disabilities (regarding clean water services in the context of the right to social protection) and the International Labour Organization Convention No. 161 of 1985 on Occupational Health Services (regarding sanitary installations in the context of a healthy working environment).

A variety of other international and regional treaties, declarations and statements also recognize the human right to water. As early as in 1977, the United Nations Water Conference of Mar del Plata stated that “all peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs” (UN, 1977). However, the right to water is not recognized by all such international meetings as a matter of course. For example, at the 5th World Water Forum, the Istanbul Ministerial Statement of 22 March 2009 referred to water and sanitation as a human *need* rather than a human *right* (WWC, 2009a). Civil society organizations attending the forum had sought to change this, since the right to water had been acknowledged in previous drafts, but they were not successful (WWC, 2009b). This points to a lack of universal consensus about whether there is in fact a “right to water”. Recent United Nations resolutions also

¹ The Bill of Rights consists of the Universal Declaration of Human Rights (1948) and the two International Covenants, on Economic, Social and Cultural Rights (1966) and on Civil and Political Rights (1966).

refrain from affirming a right to water, whilst confirming that there are “relevant human rights obligations related to equitable access to safe drinking water and sanitation (UN, 2008).

3.2. Content of the right

The right to water is defined by the CESCR in its General Comment 15, which states that the “human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses” (UN, 2002). Discussions about the content of the right to water focus primarily on drinking water and other domestic uses, such as washing, cleaning and cooking. This aspect is fairly easy to define and enjoys increased recognition as a human right. Other uses are also relevant to human rights, in particular water for food production (linked to the right to food) and for environmental services (linked to the right to health).

Although water uses for subsistence food production and watering of household animals may to some extent be considered to fall within the right to water and the right to food, it should be borne in mind that the right to food does not convey a universal right to produce food, but rather that people should be able either to produce it or buy it (UN, 1999). It should also be noted that CESCR has stressed adequate access to water for subsistence farming and livelihoods of indigenous peoples, according to the prohibition in the two International Covenants (see footnote 1) against depriving a people of its means of subsistence (UN, 2002). It may also be argued that there is a right to water for food production to the extent that it is necessary to satisfy minimum essential levels of realization of the right to food, for those who depend on subsistence agriculture (UN, 1999).

There are three main aspects of the content of the right to water in the narrower sense: quantity, quality and accessibility (UN, 2002). For quantity, adequate household needs for ensuring that all health concerns are met have been defined by the World Health Organization as 50–100 litres per day, depending on the circumstances (Howard and Bartram, 2003). An absolute minimum to maintain life is considered 25 litres per day, but this is not sufficient to maintain hygiene, for instance (Hutton and Haller, 2004). Needless to say, the quantities needed for food production and environmental services are much higher. Therefore, beyond household needs (which should enjoy priority (UN, 2002)), human rights provide only limited guidance on how to prioritize the different needs. As regards quality,

CESCR's General Comment 15 states that water for personal and domestic uses must be safe and free from substances constituting a threat to a person's health (UN, 2002).

Discussions about accessibility of water distinguish between physical and economic accessibility, and also include the question of equitable access and non-discrimination. Physical accessibility refers to the distance from home, school or workplace a person has to cover to collect water or to use water services. Economic accessibility refers primarily to affordability, in particular for the poor. As noted in earlier chapters, the poor in urban areas often have to pay more than the middle classes for their water (UN, 2007). Closely linked to this issue is the question of disconnecting households from water supplies for non-payment of water charges, also discussed earlier. Within the context of the right to water, it may not be considered lawful to deprive persons of their basic water needs of around 50 litres per day if they are unable, for reasons beyond their control, to pay the charges.

3.3. Realization of the right

The recognition of water as a human right triggers corresponding state obligations. Experts on socio-economic rights have developed an analytical framework which explains that rights such as the right to water carry both negative and positive obligations (Eide, 1989). The right to water thus carries obligations by the state to respect, protect and fulfil the right. The obligation to *respect* means that the state must refrain from interfering with existing access to safe drinking water in terms of availability and quality. The obligation to *protect* obliges the state to enact adequate legislation to ensure that non-state actors do not interfere with access to water, for example by depleting groundwater or polluting water resources. When water services are operated by the private sector, the obligation to protect means that the state must enact an adequate regulatory framework and controls to ensure equitable and affordable access to water. The obligation to *fulfil* can be disaggregated into the obligation to facilitate, promote and provide access to water.

In practical terms, a country that wishes to ensure that it complies with its obligations with respect to the right to water must first assess who does not have access to affordable and safe water and whether the current policies and programmes are sufficient to ensure that this will be redressed. Drinking water policy must be deliberate about ensuring affordable access to the poor

without discrimination. There is a need for constant monitoring of progress towards better access, both from a technical and from a human rights point of view. Civil society can play a major role in empowering rights-holders to know and claim their rights with regard to water and in demanding better policies through advocacy and lobbying. Civil society can also usefully monitor state efforts to realize human rights, either independently or in cooperation with national human rights institutions.

A number of countries recognize the right to water as an enforceable human right in their constitutions (e.g. Bolivia, Ecuador, South Africa, Uruguay). Many other countries recognize the right to water not as an individual right, but as a directive principle of the state, which may not be directly enforceable by courts (e.g. Cambodia, Colombia, Eritrea, Ethiopia, Gambia, Guyana, Iran, Laos, Mexico, Nigeria, Panama, Portugal, Uganda, Venezuela). Access to water or its protection is often linked to other human rights, such as the right to environment (as in Cambodia, Laos and Panama), the right to natural resources (as in Eritrea and Uganda) or the right to property (as in Mexico).

A number of countries have recognized the right to water in their national legislation (e.g. Algeria, Belgium, Burkina Faso, Ukraine). Disconnection from domestic water supply for non-payment has been forbidden by law or case law in many countries (e.g. Argentina, Australia, Austria, Belgium, Brazil, Ireland, Luxembourg, Mexico, New Zealand, Norway, Spain, Sweden, Switzerland, Ukraine, United Kingdom) (Smets, 2006).

3.4. Process of achieving the right

A human rights-based approach to water management combines a focus on the outcome (that everyone, in particular the most vulnerable, has access to safe, sufficient and affordable water) with concerns about the process employed to achieve that outcome. The key rights involved are the right to information, the right to participation and the right to a remedy.

Information

Implementing the right to information means ensuring that users of water are informed about the water distribution process. For example, water users should be informed of water quality, prices and any major decisions that water managers might make (Smets, 2006). This type of transparency allows

users to hold government authorities or water distributors accountable for any failures to comply with the law.

Many countries already require that information on drinking water be distributed to the public. This information can include data on the quality of drinking water and annual reports that are published by water service managers (Smets, 2006). It should also include information on government activities, for example, if the government is considering amending its laws or policies or authorizing activities that may have a harmful effect on water resources.

Participation

The right to participate implies the right of users and those otherwise affected to actively participate in water development and management (Filmer-Wilson, 2005). Participation, to be effective, requires access to education and information, a role in decision-making and monitoring processes and mechanisms for redress (Scanlon *et al.*, 2004). A knowledgeable public is better able to react and make its voices heard (Scanlon *et al.*, 2004).

Public participation may include the formation of committees that have certain rights or duties with respect to water management organizations or companies. The public may also participate through representative bodies with which the government must consult before making decisions. Some countries (e.g. Honduras) are obligated to carry out public surveys or referenda before making any major decisions such as privatization of the water supply. Other countries (e.g. United States of America) hold hearings before making decisions, to answer any questions or respond to any comments or concerns the public might have (Smets, 2006).

Remedies

The right to a prompt and effective remedy is essential for government accountability. This means that administrative recourse should be easily accessible at all levels, for example to enable the public to challenge unfavourable decisions regarding water allocation or management. In addition, national human rights institutions in many countries can receive complaints about violations of the right to water and recommend suitable remedies. Unless access to courts is secured as a final recourse, however, these other remedies may be ineffective.

The right to an effective remedy goes beyond access to administrative or judicial processes. Where mechanisms to enforce rights are inadequate or ineffective, governments may need to provide new and more effective ones (Scanlon *et al.*, 2004). States also have a responsibility to ensure that individual rights are not infringed by government or private actors.

IV. CONCLUSION

Many writers have labelled the twentieth century as the century of water resources development and over-exploitation. The hope is that the 21st century will see comprehensive approaches to water resources management which will more effectively allocate water and maximize efficiency of water use. As seen throughout this book, there are scientific and regulatory barriers to achieving this goal, and all must be addressed together.

The scientific component requires continuing work toward a detailed understanding of the water cycle and the variety of ecosystem and human needs within a watershed. To be most effective, water legislation must reflect the latest scientific understanding, whilst taking into account socio-economic and equity concerns.

Given the wide variety of available water resources and existing legislative frameworks, each country will face unique challenges in transforming its water resource management system. For example, many countries are subject to binding international agreements or make use of shared water bodies that are managed by transnational entities, which may constrain their ability to access the water or control its quality. Countries may also have to harmonize domestic legislation where different laws assign responsibilities for water to a variety of agencies or ministries. Governments must devise cross-sectoral strategies and solutions to implement integrated management.

It is hoped that this book will help lead to a better understanding of the steps necessary to design and implement effective water resources management systems underpinned by strong regulatory frameworks. Water plays a pivotal role in every aspect of human life, from economic growth and social development to health. Continuing efforts are needed to improve national and international responses to growing water scarcity. Well-designed management and regulatory systems will make it possible to provide water where and when it is needed for the full range of human and ecosystem uses.

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