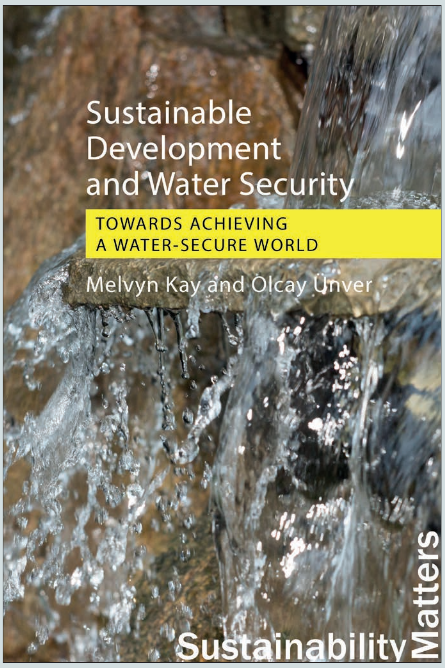

Sustainable Development and Water Security

TOWARDS ACHIEVING A WATER-SECURE WORLD

Melvyn Kay and Olcay Ünver

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"Two of the most salient objectives animating our world today are sustainable development and water security. Whether you are a seasoned water expert, stakeholder, academic, policymaker or interested citizen, this book offers an accessible path to the heart of these critical objectives."
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Drawing on years of real-world experience of water resources management, the authors provide a comprehensive survey of the central issues surrounding water security and sustainable development. They offer an in-depth critical review of SDG6, while also correcting many of the misunderstandings that have lead to poor decision-making in the past. Engagingly written and accessible to the non-professional, the book uses case studies from around the world to illustrate the key challenges to achieving a water-secure world.

Melvyn Kay has over 40 years' international experience in water resources, including in the Middle East and Africa. He has taught at Cranfield University and was chief editor of UN FAO's flagship report *The State of the World's Land and Water Resources for Food and Agriculture 2021*.

Olcay Ünver is Professor of Practice on the Environmental and Resource Management Program at Arizona State University and a member of the Water Policy Group. He has led water programs and activities for FAO, UN-Water and UNESCO.

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SUSTAINABLE DEVELOPMENT AND WATER SECURITY

Towards Achieving a Water-Secure World

MELVYN KAY AND OLCAY ÜNVER

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To Judith for her constancy, and Mohamed Ait-Kadi for our inspiring times together.
Melvyn Kay

To my wife and life partner, Rayiha, for her unwavering support, endless patience and loving encouragement.
Olcay Ünver

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PREFACE

Imagine taking a refreshing sip of clean water – a simple act many of us take for granted. Access to clean water is the most basic human right of all. Yet, this fundamental right remains a daily struggle for millions worldwide. Water permeates every aspect of our lives and is receiving world attention as we face escalating threats to our limited water resources due to burgeoning population pressures, life styles and climate change. Water resources planning and management cuts across all sector boundaries and disciplines. Once the domain of civil engineers, today, professionals from all walks of life engage in water-related careers spanning public water supply, agriculture, irrigation, energy, environment and sustainable development. Myriad books and reports on every aspect of water are appearing everywhere. Most are written by water specialists, usually for water specialists. Some, like the media, dwell on the more sensational aspects of increasing floods and droughts, especially as our climate changes.

In writing this book, we are taking a different approach. We want to encourage those who do not wish to become "water experts", yet would like to go beyond the sensationalist narratives surrounding water to understand better how water affects us all, especially the steps we can take to increase water security. We anticipate our readers will include professionals and students from diverse disciplines who have or are planning careers in the water and water-related sectors. We also write for those stakeholders striving to attain other sustainable development goals (SDGs) in which water plays a part. Our ambition is to cultivate a cross-disciplinary understanding of water's intricate involvement in human activity to help readers align their actions better and create integrated solutions rather than silos and barriers.

We offer an overview of the significant challenges facing every country and describe the work of "water specialists", which we hope will be accessible and informative to all. We wish to lift the doom and gloom that pervades the water sector by offering solutions, not just problems. There are plenty of innovative actions out there, not just in technology or management fixes, but equally important are changes in how we think about and take care of water. Everyone has a part to play, not just the water specialists. Collectively, we can make sure there's enough clean water for everyone. We just have to find ways of putting these ideas into practice. It's somewhat easier said than done.

We use the UN 2030 Development Agenda and SDG 6, the "water goal", as an internationally agreed framework to tell our story. This serves as a compass for discussing and addressing water-related challenges and provides concrete targets and indicators to measure progress. SDG 6 is also designed to guide decision-makers, water planners and managers, and underscores the pivotal role of water security in achieving sustainable development.

In our water exploration, we integrate the 2030 Agenda with the fundamental principles of human rights to water and sanitation, as they hinge upon the assurance of water security. We confront the stark reality of many nations grappling with poorly regulated water resources and the complexities and importance of water governance. Poor governance is prevalent in many countries. It can allow water resources to fall into the hands of self-interested groups and become vulnerable to exploitation. This paves the way towards what is known as the "tragedy of the commons", the challenges of inequality and the 2030 Agenda's mandate "to leave no-one behind". In this context, we explore effective regulation and stewardship of water resources as vital elements of sustainable development.

A central feature of SDG 6, and of our writing, is advocacy for integrated water resources management (IWRM), the holistic nexus of water, energy, food and the environment (WEFE) and exploring the interconnections across the SDGs. This emphasizes the importance of working together to use limited water resources best. We extend this to the global level, as we face the "global commons nature of water" where all nations, irrespective of their level of development, must collaborate to regulate limited water resources. Indeed, this is the fundamental justification and hope of the UN Charter, which is to find common solutions to common problems. However, despite its importance, effective collaboration and coordination among disparate disciplines and interests often proves elusive. There is no "blueprint" solution for this, but many documented experiences offer examples of how it might be done and how not to do it.

Collaboration is often hindered when we do not understand one another or express ourselves adequately. This is common within the water sector, as those working in water supply use different jargon from those in agriculture, energy and the environment. Yet, we are all talking about the same water resource. Conversations among different disciplines sometimes sound like the biblical Tower of Babel! Confusion over hydrological terms even exists among water professionals and researchers, who should know better. Unsurprisingly, decision-makers, the media and the public are also confused. In support of clarity, our contribution is a Glossary of our vocabulary.

Finally, we wish you well as you engage with the world of water. It can be inspiring, challenging and rewarding. Let's face it: life as we know it cannot exist without it!

Melvyn Kay and Olcay Ünver

1

WATER, WATER …

"Water, water everywhere, nor any drop to drink" wrote the English poet Samuel Taylor Coleridge in 1798 in "The Rime of the Ancient Mariner". Such sentiments still reverberate over 200 years later as water has become the centre of world attention as never before. Even in the 1950s, water was reasonably available, with few demands, although some countries were never without severe floods and droughts, particularly in tropical, arid and semi-arid regions. As populations gradually increased and water demands grew, governments responded by building more storage dams and diverting rivers to maintain widespread water availability. However, since the late 1990s, the world has faced a very different future of impending water scarcity (Box 1.1). The global population has expanded rapidly and is expected to reach 9.7 billion by 2050. Innovative technologies have produced step changes in economic growth, prosperity and living standards, mainly across Europe and North America, but to such an extent that water resources are reaching their limits, and technologies can no longer keep pace with demand.

Since the late 1980s, world leaders have been sounding an alarm about an impending water crisis. The World Economic Forum, which provides an overview of shocks and trends from a business perspective every year (from 2012 to 2020), has identified water crises as one of the top five risks with a severe global impact. In 2021, a survey among national leaders from 88 countries across all regions responsible for achieving sustainable water use for over six billion people identified climate change and associated pressures on water supplies and worsening floods and droughts as the highest water-related risks facing their countries (Water Policy Group 2021). Climate change, driven by industrialization, is becoming more visible through frequent and severe floods and droughts. Shocks from international financial turmoil, pandemics (Covid-19), conflict (in Ukraine and the Middle East) and significant catastrophes like earthquakes have added to the impact on water availability, especially in areas where access to clean drinking water is already limited.

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BOX 1.1 SOME STATISTICS THAT HIGHLIGHT WATER SCARCITY

- In 2009, water demand was predicted to exceed supply by over 40 per cent by 2030 if society continues to use water at current rates, known as the "business as usual" scenario (2030 WRG 2009).
- Some 80 per cent of people living in 186 countries are water insecure, including 8 per cent who are critically water insecure. Only 12 per cent (1 billion) live in water-secure countries, primarily Europe and the Americas (MacAlister *et al*. 2023).
- In 2023, 2.2 billion people (27 per cent of the global population) lacked "safely managed drinking water", meaning water at home, available and safe; 3.5 billion (43 per cent) lacked safely managed sanitation services, including 419 million who defecated in the open; 2 billion (25 per cent) lacked basic hygiene services, including 653 million with no handwashing facility at home (WHO & UNICEF 2023).
- Globally, agriculture is responsible for withdrawing 70 per cent of all freshwater for food, feed and fibre production (FAO 2022).
- By 2050, the global food demand is expected to increase by 50 per cent to feed 9.7 billion people without harming the natural environment and aquatic ecosystems (FAO 2022).
- Over 783 million faced hunger in 2022 (FAO *et al.* 2023), and nearly 670 million may still face hunger in 2030 (FAO *et al*. 2022).
- The world's land, soil and water are under pressure and are "systems at breaking point" (FAO 2022).

Increasing water scarcity is undoubtedly a primary concern for the future of our planet and people's lives and livelihoods as nations seek sustainable water security (Box 1.2). Concerns about water scarcity may seem strange to many when 71 per cent of the Earth's surface is under water. However, only 1 per cent is readily available as freshwater in lakes, rivers and water stored in underground aquifers and soils. Freshwater, in sufficient quantity and quality, is essential for all aspects of life. It is an integral and vital part of everyone's daily lives and touches everything we do. It is embedded in all aspects of development, such as food security, health and poverty reduction, and sustains economic growth in agriculture, industry and energy generation. Without drinking water, we would not survive more than a few days; without food, we may live for only a few weeks. Yet, as we seek to satisfy the demands, we risk over-exploiting the natural resources and the aquatic environment on which every aspect of life depends.

BOX 1.2 WATER SECURITY IS …

… the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

Source: UNU-INWEH (2013).

1.1 Water security: balancing supply and demand

Although enough freshwater is available globally, water scarcity is caused by a mismatch between when and where people need it, and its availability and accessibility. Physical scarcity occurs when there is not enough water to meet all demands. It may also be economic, resulting from a lack of investment in water infrastructure and technology or human capacity to organize and manage available water resources. This differs from water shortages, a natural phenomenon when demand exceeds supply for short periods during drought.

Water security is about addressing water scarcity and balancing water supply: increasing water availability and managing demand, conserving water by implementing policies or measures to control or influence the water we use (see Chapter 2). The principle is similar to balancing household income and expenditure. Money is precious and limited, so knowing how much is coming in and how it is being spent is essential. One of Charles Dickens' characters expressed the issue well. "Mr Macawber's Principle" suggested that when income exceeds expenditure, there is happiness, but when expenditure exceeds income, even by a small amount, there is misery (Dickens 1850). The same principle applies to balancing business and government finances, for which accountants have developed special management tools. Thus, it is paradoxical that we do not give the same attention and priority to accounting for water as a precious and limited resource. Long-term rainfall records, river flows and groundwater levels help us determine water income (supply). Mathematical models and forecasting tools help us estimate outgoings for people, industry, agriculture and the environment (demand) to produce an acceptable water balance. Special water accounting and auditing tools are available to help water resources planners understand and monitor the increasingly complex task of providing sustainable and reliable water services to support good water governance. We just need to learn how to use them (Chapter 4). Like household budgeting, water accounting is not always easy. Rainfall does not conveniently come at the right time, in the right place and quantity, so we must contend with times when there is too much water (floods), others when there is too little (droughts) and, increasingly, when it is too dirty (water quality). Equally, it is difficult to predict demand, which depends on population growth and migration, lifestyle changes, economic growth and assessing the impacts of climate change, which are more noticeable in water resources as the frequency and severity of extreme floods and droughts increase.

Storing water has long been a solution to smoothing out some differences between the extremes, and water transfer schemes can move water from place to place. However, water is heavy and bulky, and storing and moving large quantities around is costly in terms of money, energy and environmental impacts. In the past, constructed storage (dams and reservoirs) was the preferred choice, but interest is growing in exploiting natural and nature-based storage options. Underground aquifers are a good example. They store vast quantities of water; they are a popular source of drinking water and irrigation, but in many countries over-exploitation is already putting such resources in crisis. Many countries augment their water resources by importing goods produced in water-rich countries. For example, importing one tonne of cereal grain is equivalent to importing about 10 tonnes of water used to grow it: a substitution known as "virtual water trading" (see Chapter 5).

On the supply side, many governments in developing countries, with support from international funding agencies, invested heavily in the 1970s and 1980s, constructing dams, canals, pipelines and pumping stations to secure public water supplies, irrigate agriculture and generate hydropower. In the drive for economic growth, little thought was given to possible environmental damage and the impacts of future water needs. Indeed, "environment" was not part of everyday language as it is today. Investment focused on economic growth, and the prevailing attitude was to fix environmental problems as and when they occurred and when economies could afford to do so. This attitude still prevails in many developing countries where governments cannot afford to prioritize the environment over people and living standards. However, attitudes are slowly changing as people become more aware of environmental damage caused by over-exploiting rivers and groundwater and discharging untreated wastewater into freshwater bodies, further reducing freshwater availability. Ironically, many of those immense water infrastructure projects undertaken in the 1970s and 1980s, of which nations were proud and enjoyed enormous economic benefits and water security, would probably not be acceptable today to an environmentally aware population.

Care for the aquatic environment is now well recognized, but so is the need to continue providing water for people and economic growth. There are also concerns about the state of water infrastructure in the developed countries, which was built mainly in the last century. It is ageing, proving inadequate, and in some cases no longer fit for purpose: leaking water distribution networks that struggle to supply oversized cities, wastewater treatment systems that cannot cope with increasing discharges and emerging contaminants, reservoirs and regulating structures no longer able to cope with storms and droughts as the climate changes, and bulky and sluggish irrigation networks that are inefficient and costly to rehabilitate, modernize and maintain. The debate over development vs the environment continues to be at the forefront of all natural resources planning, especially in the water sector, since the Brundtland Report in 1987 introduced the concept of "sustainability" into the development vocabulary and emphasized the importance of the aquatic environment (WCED 1987). One of the guiding principles of sustainable development is acknowledging that the natural resources supporting development, especially water, land and soils, are limited and essential for supporting vital ecosystem services. Development can be sustainable only if it works within these constraints, over time and across sectors and locations (Weitz *et al*. 2014).

A growing problem that limits supply is water that is too dirty. Water pollution is increasing globally as water use increases, resulting in more wastewater being discharged untreated (global estimate is 80 per cent) into rivers, lakes and the sea from municipalities and industries, effectively polluting and reducing the amount of freshwater available. Runoff and return flows, primarily from agriculture, are also a significant source of pollution.

Linked to the dirty water story is the potential for water reuse. Treated wastewater is often discharged into the sea and is lost. Seeking to reuse this water is not new, but there is renewed interest because of water scarcity. It is part of the current thinking about the "circular economy". Like other valuable resources, industries are finding ways to recycle waste rather than throw it away. However, not everyone is happy about using treated wastewater, particularly for domestic use, because of the "yuck" factor.

Desalination is another option to increase supply and is widely used in the Gulf States, across the Middle East and in the Mediterranean countries where water scarcity is most acute and other options are unavailable. Cost and the reliance on fossil fuels to power the process are still prohibiting factors, although some countries are taking advantage of the surging interest in alternative renewable solar and wind energy. In parts of south-east Spain, desalination is discouraged because of pollution, as discharges from treatment plants produce plumes of highly saline water that threaten marine environments.

On the demand side, many countries practise "demand management", which is about reducing demand and making better use of available water supplies. For public water supplies, this is much more difficult to implement as the issues are more sociological than technical fixes (see Chapter 4). In most developed countries, people are using far more water than they used to. For example, two showers a day have become the norm for some, and this led one social scientist to comment (somewhat tongue-in-cheek) that installing shower cubicles in the kitchen instead of a private lockable room would drastically reduce water use in the home! Increasing supply often appears to be a more attractive option than finding ways of changing the hearts and minds of millions of people to use less water.

Other demand pressures come from irrigated agriculture, which accounts for over 70 per cent of all freshwater withdrawals globally and is considered a place where significant water savings are possible. Despite taking the lion's share of available freshwater, agriculture does not usually get the attention given to public water supply (14 per cent). Droughts, particularly, put a lot of pressure on water systems as water demand is usually greatest when supplies are least available. Water and energy are also closely linked. Public water supply, agriculture and industry all need energy to pump water, treat wastewater, irrigate crops and desalinate. In turn, the energy sector relies on water to cool thermal power plants, provide hydropower and grow biofuels.

Climate change significantly affects water resources, as well as population growth, mobility, urbanization, technological change and economic growth, which in turn impact on water availability. Unfortunately, climate change is an easy target and handy for some to escape the responsibility of poor decision-making. One example is local planning authorities that allow residential development in flood plains and use climate change as the reason why housing is flooded and damaged during heavy rainfall. In the UK, some people like to live in village cottages with an attractive "old world" address like "Water End" as they overlook a stream. When it rains, they soon discover why the cottage has this name, when the stream becomes a torrent and flows through the house! Tolerated in days gone by, but not anymore.

Climate change is most visible in its effects on water resources through its links with severe droughts, floods, melting glaciers and ice caps, but its impact on the supply–demand balance is difficult to quantify accurately. In many instances, it is not so much reduced water volume but rainfall intensity and timing changes that make it more difficult to capture and manage it using conventional storage. An emerging issue is water that is too warm, reflecting the challenges of a warming climate and cooling-water from power stations that cause water temperatures to rise and toxic algal blooms on rivers and lakes that are harmful to people and aquatic flora and fauna.

Many weather events we experience reflect the intricate and powerful mechanisms already at work within the Earth's climate, and separating these from human-induced climate change is complicated. An example is the El

Niño-Southern Oscillation (ENSO), which drives powerful climate variability in and around the tropics and beyond. Climate change may well exacerbate such variability.

1.2 Different people, different views and priorities

Although water is essential, not everyone holds the same views. Here are two typical water-using profiles.

Those living *in the developed countries* have become so accustomed to having reliable, good-quality and inexpensive water supplies that many people take water for granted. They give little thought to where water comes from and how it is cleaned and delivered to our homes. They pay their water bills and expect a water service much like they buy other goods and services. Decades of planning, investment, engineering and effective governance have created well-managed water-supply systems that enable clean water to flow from our taps despite occasional significant and often unexpected water supply and demand variations. People also expect sewers (piped systems) to take away dirty water (sewage), and for water authorities to clean it to a standard that allows it to be discharged safely into rivers and the sea. If suitably treated, water can be reused in some cases, if not immediately for domestic use, then for agriculture and industries.

Most Europeans and North Americans are unaware of how much water they use. In 2020, the average domestic water use in the European Union was about 125 litres/person/day, yet in a survey in the UK, over 45 per cent of people thought they used less than 20 litres/person/day (The Economist 2022). Perhaps even less well known is that the average European consumes about 3,500 litres/person/day embedded in their food, and modern lifestyles are polluting and degrading freshwater resources. Yet people also expect to enjoy a vibrant aquatic environment where rivers, lakes and wetlands enhance the landscape, support flora and fauna and provide leisure and pleasure activities, all of which require good-quality water.

However, people are gradually becoming more aware of water problems. They see the devastating effects of flooding following intense rainfall and are aware when water companies restrict supplies during severe droughts. They notice when water starts to bubble up in the streets from burst pipes due to ageing infrastructure. Some countries are losing as much as 25 per cent (e.g. London) to 50 per cent (e.g. in the US and Mexico City) of treated water through leakage from systems needing replacement. Even in homes, a tap (faucet) leaking 20 drips per minute can waste 14 litres daily. People notice when rivers and wells run dry in the summer, and environmental groups highlight the impacts on aquatic ecosystems. They may feel unwell after swimming in rivers and coastal

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waters that do not smell good when sewage overwhelms the treatment works and is discharged untreated during heavy storms.

In developing countries, attitudes to water are very different. Water is high on household agendas. Water and water-related services are compromised by arid and semi-arid climates, a lack of infrastructure, inadequate institutional and human capacity to manage water services and weak governance systems. Since the late 1980s, concerns have grown internationally about the lack of clean water and poor or non-existent sanitation facilities, particularly among impoverished people in rural and urban settings. According to the United Nations, for some 2.2 million people, finding, collecting and using clean water while living in unsanitary conditions are common burdens that focus attention on the importance of water in everyday life for health and survival. In such circumstances, it is unsurprising that water for people and economic growth are given priority over environmental considerations. Much progress has been made on water for people since the turn of the century, known collectively as WASH (water, sanitation and hygiene). However, a great deal still needs to be done. Effective WASH is still far from reality for many and remains a vital and highly political aspect of water management. Domestic water, when available, can be as little as 10–20 litres/person/day, and less than 1,000 litres/person/day is embedded in diets, reflecting severe problems of poverty, hunger and malnutrition. Floods and droughts do not just affect economic growth; they are linked to disease, famine and untimely deaths for many.

There is, of course, no simple dividing line between these two contrasting profiles. In the 56 countries that make up the UN pan-European region, including North America and a part of Asia, where good progress might be expected, about 19 million people still do not have access to improved water sources and 67 million lack access to improved sanitation facilities (UNECE 2022). Together, they highlight that water scarcity is a problem everyone faces, but in different ways. It is driven primarily by population growth, lifestyles and climate change. Priorities and responses differ, depending on a country's unique natural resource endowments and socioeconomic and environmental circumstances. Sustainable development is a universal challenge for all countries, requiring fundamental changes in how societies consume and use natural resources.

1.3 Does water have value?

Today, primarily due to media attention, many people are aware of water's importance, yet how many attach value to it in the way we value other commodities, goods and services? Much sought-after commodities command high prices when supplies are limited. Yet, however we stress the importance of water and how we cannot live without it, it appears to have little or no value. The lack of awareness and understanding of the importance of water has come at an immense cost that is undermining human and planetary health: the World Wide Fund for Nature refers to this as "water blindness" and estimates the total quantifiable economic use value of water at approximately US$58 trillion, equivalent to 60 per cent of global gross domestic product (GDP) in 2021. The direct value of goods and services for households, agriculture and industries is valued at US$7.5 trillion annually. Indirect benefits to ecosystems are estimated to be US$50 trillion annually (in 2021) and, as such, the benefits of freshwater are being chronically undervalued (WWF 2023).

In 1776, the economist Adam Smith (1776: Bk 1, ch. 4) wrote: "Nothing is more useful than water, but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any use value, but a very great quantity of other goods may frequently be had in exchange for it." It is paradoxical that water is essential for survival but has little value in exchange (and the price of water is typically low). Smith suggests that while diamonds are extremely valuable in exchange, they are superfluous for survival (and their price is very high).

The "diamond–water paradox" is now explained in introductory economics textbooks using marginal utility theory. An additional water unit has very low utility (value) to someone when it is already in plentiful supply because the basic water needs, which are essential for survival, have already been met. Diamonds are so valuable to people because they are scarce; their marginal utility is high because of their aesthetic beauty and social status to the owner, and few people have them.

Whittington (Whittington, Sadoff & Allaire 2013) argues that water resources are important, but not the sole or primary driver of economic development and human well-being. Water resources are integrally linked to other key factors of production. So, we must avoid a narrow focus on water use efficiency (WUE) or "water footprints" (see Sections 2.6.1 and 5.3.2) as guides for optimal water use. He argues that water is not just part of the economy but is embedded within it. Without it, the economy could not function. Water will be scarce in some places where other factors of production are plentiful (e.g. the Gulf States), and water may be plentiful in some areas where other factors are scarce (e.g. Central Africa.) Determining the optimal mix of resources and the sustainability of water withdrawals for a given location is more critical than simply minimizing water use (Whittington, Sadoff & Allaire 2013).

Perhaps the critical question to ask about the value of water is: *What would you be prepared to pay for water when there is no water?*

1.4 About Covid

The Covid-19 crisis has caused enormous disruption to sustainable development. However, even before the pandemic, the world was seriously off-track in meeting SDG 6. New Covid-19 variants and continuing vaccine inequity, rising inflation, significant supply chain disruptions, policy uncertainties and unsustainable debt in developing countries caused the global economy to slow down again at the end of 2021.

While handwashing is the first line of defence against the coronavirus, the Water Policy Group reports that only 42 per cent of the water leaders surveyed in 88 countries considered the pandemic made their respective governments more concerned about handwashing. In comparison, 47 per cent said it made no difference. On the question of how the pandemic affected their priorities regarding drinking-water services and sanitation, 57 per cent of national water leaders advised that it made this more urgent for them (Water Policy Group 2023).

1.5 SDG 6 and this book

This book explores the many facets of water security briefly described in this introductory chapter through the lens of SDG 6: Ensuring availability and sustainable management of water and sanitation (Box 1.3). SDG 6, often called the "water goal", is one of 17 SDGs involving 163 targets and 230 indicators in the United Nations 2030 Agenda for Sustainable Development (2030 Agenda) that embodies aspirations for achieving a future without poverty or hunger, and a more just, equitable, peaceful and sustainable world that leaves no one behind (United Nations 2015)

SDG 6 (plus SDG 11.5) captures all the water challenges facing us, particularly those responsible for managing water resources. SDG 6 offers an internationally agreed framework for discussion and action to resolve problems, with targets for improvement and indicators of progress designed to guide policy-makers, water planners and managers towards a water-secure world.

Although SDG 6 is a well-established part of the 2030 Agenda, this was not always the case. A brief history may help to understand prevailing and changing attitudes to water resources since 1970, and how we arrived at SDG 6.

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BOX 1.3 SDG 6: ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally.
6.4 By 2030, substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
6.5 By 2030, implement integrated water resources management (IWRM) at all levels, including through transboundary cooperation as appropriate.
6.6 By 2030, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
6.a By 2030, expand international cooperation and capacity building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
6.b Support and strengthen the participation of local communities in improving water and sanitation management.

SDG 11: Make cities and human settlements inclusive, safe and sustainable

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global GDP caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

Source: UN-Water (n.d.).

The sentiments embodied within SDG 6 first gained international prominence in 1992 at an International Conference on Water and the Environment (ICWE) in Dublin, Ireland. This brought together people worldwide to provide input on freshwater problems for the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, convened in Rio de

Janeiro, Brazil, in 1992. This was the most significant global conference since the first United Nations Conference dedicated to water in Mar de Plata, Argentina, in 1977. It was the catalyst that highlighted growing concerns over freshwater resources and established what became known as the "Dublin Principles" (Box 1.4). They provide the foundation for what is now known as integrated water resources management (IWRM), a central feature of SDG 6 (target 6.5). IWRM is now widely accepted as the most effective way to achieve sustainable water use when supplies are limited.

BOX 1.4 THE DUBLIN PRINCIPLES ON WATER AND SUSTAINABLE DEVELOPMENT

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Water development and management should be based on a participatory approach involving users, planners and policy-makers at all levels.
- Women play a central part in the provision, managing and safeguarding of water.
- Water has an economic value in all its competing uses and should be recognized as an economic good.

Source: UNCED (1992).

In 1996, the World Bank and others founded the Global Water Partnership (GWP) to champion IWRM. GWP now provides a forum for dialogue among corporations, governmental agencies, water users and environmental groups to promote stability through sustainable water resources development, management and use. GWP summarized IWRM principles and articulated the vital link between water resources and sustainable development: economic efficiency in water use, social equity and environmental and ecological sustainability (known as the "3Es"; see Chapter 3).

Towards the end of the twentieth century, world leaders drew attention to the lack of clean water and poor or non-existent sanitation facilities, primarily among impoverished people in developing countries. In 2000, the United Nations set the Millennium Development Goals (MDGs) to address these and other pressing development issues. Eight MDGs set out the elements of international development policy, including a focus on WASH in MDG 7: *Ensure* *environmental stability*, which included target 7C: "to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation" by 2015. The original wording referred only to drinking water, but this was modified to include sanitation following the 2002 Johannesburg Declaration on Sustainable Development (sometimes referred to as the Earth Summit 2002), where the MDG plan of action was agreed to focus on sustainable development and multilateralism (United Nations 2002).

This was a bold international plan, and actions to achieve MDG 7 enabled millions to access clean drinking water, sanitation and basic hygiene. In 1990, the reference year for measuring MDG progress, global coverage for improved drinking-water sources was 76 per cent, and for sanitation facilities 54 per cent. By 2015, access to drinking water rose to 88 per cent and sanitation facilities to 77 per cent (UNICEF & WHO 2015).

With the benefit of hindsight, the MDGs exposed significant shortcomings. Although it is a vital humanitarian and highly political issue, the focus on WASH largely ignored the growing concerns among water professionals over the broader issues of water scarcity. Water resources were not featured except for the targets and indicators under MDG 7: drinking water and sanitation (target 10, indicators 30–31) and water stress (target 7A), with an indicator for which no concrete target was set. Water resources were implicit in MDGs, such as halving extreme poverty rates, reducing child mortality, halting the spread of HIV/AIDS and other diseases and ensuring environmental sustainability, all of which are highly water dependent. The MDGs also paid little attention to the interactions between goals and whether the increasing water demand could be met without degrading the natural resource base and the underlying water-related ecosystems (Weitz *et al.* 2014).

In 2015, the 2030 Agenda and the SDGs were built on the foundation created by the MDGs. The Agenda invited everyone (not just those in developing countries) to change how natural resources are planned and managed from a traditional "silo" approach to one that recognizes the interconnected nature of resource use. It recognizes that water resources are a limiting factor in social development and economic growth and that we need to look at the entire water cycle and not just focus on sectoral targets. It takes account of the global concern over water availability and water quality, not just to meet water supply and sanitation needs but also to satisfy the world's increasing demand for water in the face of rapidly expanding populations, agricultural intensification, migration and urbanization, increasing energy demand, industrial production and pollution, and climate change.

Although water was widely accepted as an integral part of sustainable development, not everyone initially accepted the need for a dedicated water goal. The importance of water was not in doubt but, as in the MDGs, it was assumed

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that each SDG would account for the water it uses. However, this raised serious concerns among water leaders that this failed to recognize water as a limited resource and would perpetuate the silo approach to managing water that still prevails in most countries and is contrary to the 2030 Agenda's aspiration for integration. It also failed to recognize the scale and complexity of the world's huge, multidimensional water challenge (Ait-Kadi & Kay 2020). If left to individual SDGs, water was in danger of "being out of sight and out of mind".

The advent of SDG 6 was the groundwork undertaken by UN-Water, with consultations for the Future We Want, post-Rio/ pre SDG, and preparatory work on indicators, monitoring and reporting framework, developed by a task force led by Olcay Ünver (author) (UN-Water 2009, UN-Water 2010). Ünver was also a member of the UN-Water team that developed the first draft of SDG 6, a dedicated water goal, which provided the starting point for a large-scale advocacy that included the Dushanbe Water Process and Budapest Water Summits. Eventually, most international water-related organizations and governments concluded that water was so crucial to development that it should have its own dedicated goal (SDG 6).

Despite this broad acceptance, SDG 6 still has the title "Clean Water and Sanitation", which clings to the past rather than recognizing the broader implications of managing scarce water resources. Such is the politics of water!

Whatever the title, the advent of SDG 6 was a major "game-changer" for water and water-using sectors. The goal flags water as needing serious attention in its own right and puts primary responsibility for water management in the hands of the water sector (Ait-Kadi 2016). The new goal goes much further than WASH, embracing the entire water cycle and explicitly recognizing that water impacts on the whole 2030 Agenda. It targets water quantity (scarcity) and quality, WUE and water-related ecosystems. It promotes a basin approach to water management and the need for an integrated approach that goes beyond national administrative boundaries and embraces transboundary water management that affects almost half the Earth's land surface (Ortigara, Kay & Uhlenbrook 2018). A major step forward for all UN member states was recognizing the significance of IWRM as a coping strategy for managing water scarcity and reconciling many competing and potentially conflicting water demands. Accepting IWRM also reinforces the importance of integration among all the SDGs. It highlights that all must work together for each to succeed.

IWRM is a simple and attractive concept, but fiendishly difficult to put into practice and not easy to measure progress. Because of its importance, we develop the IWRM theme further in Chapter 2, how progress is measured in Chapter 3 and how it might be achieved in Chapter 4.

Chapter 2 offers a starting point for those relatively new to water resources planning and management who want to understand and appreciate its many facets. In this chapter, we look at how key professionals in the water sector view

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their role in water planning and management. This is not meant to be a textbook on water resources planning and management. Rather, it is a collection of "stories" designed to improve understanding of what water resources planning and management means to different people working in the sector. Today, many disciplines are involved in water management, so the "stories" are limited to those most directly involved in planning, designing and managing water resources. They include hydrologists, water resources planners, water supply and sanitation engineers, irrigation engineers, energy engineers and freshwater ecologists.

Professionals already involved and focused principally on one aspect of water management may also find it helpful to dip into those areas with which they are less familiar. Equally, it is incumbent on those who indirectly influence decision-making as water users to appreciate how others use and view water so as to avoid misunderstandings that can and have led to inappropriate plans with serious financial consequences.

Chapter 3 offers a critical review of SDG 6's six targets, indicators and approaches to monitoring progress. Also discussed are the limitations of current indicators, and attempts being made to improve them without necessarily overcomplicating the process and rendering them unworkable, particularly when data are scarce.

Chapter 4 seeks to lift the gloom of Chapter 3, which charts the limited progress made in meeting the targets set for SDG 6 for 2030. It responds to the growing optimism among the international community about achieving the targets and reaching a sustainable water-secure world, although, realistically, this will likely be some (unspecified) time after 2030. There is no shortage of good ideas. Some require practical actions and are highly visible, such as the "hardware": installing more taps and toilets, building reservoirs and drilling boreholes. However, some actions are far more complex and challenging: the "software" of water development, such as the need for good water governance, finance and putting IWRM into practice to enable the hardware to function properly. These challenges are not in plain sight; they are persistent and may take decades to resolve. As such, they are often side-lined in favour of more visible and prestigious capital investments. Unfortunately, they do not disappear. They are just as essential to achieving SDG 6 as the hardware.

Chapter 5 links with other SDGs, looking beyond the confines of SDG 6 to assess water's impacts on society, the environment, the economy and food production. This is often described as the "WEFE (water, energy, food and environment) nexus", highlighting the connections and interdependencies across the water-using sectors.

There are myriad and complex connections among all SDGs, and how we deal with issues of water security will affect and be affected by the ability to achieve other SDGs. The 2030 Agenda emphasizes the importance of these interlinkages and the immense benefits an integrated approach can bring to sustainable development. Integration can help to ensure appropriate timing and sequencing of policy and institutional reforms and public investments so that limited resources are used more efficiently and sustainably. Equally, integration binds together all the SDGs so that progress in one affects progress in others. Thus, progress towards SDG 6 will be determined as much by what happens in other sectors as within the water sector.

To conclude, Chapter 6 is a final word on our journey exploring the role of water security in sustainable development and the intricate relationship between water and global challenges. It is not just a resource but a critical element at the heart of sustainable development in which scarcity hinders progress on issues like climate change, poverty and hunger, biodiversity loss and environmental degradation. All of which is recognised through the dedicated goal, SDG 6, within the 2030 Sustainable Development Agenda and established targets which cover the entire water cycle.

2

UNDERSTANDING WATER BETTER AND WORKING TOGETHER

Throughout most of the twentieth century, water resources planning was mainly in the hands of civil engineers. They planned, designed and built the infrastructure to monitor, store, control and manage water resources. It was essentially a "top-down" process with little stakeholder involvement, and still is in many countries. However, the impacts of water scarcity, increasing demand and competition among water-using sectors and society's growing awareness and interest in the natural environment have meant that many public and private sector organizations now engage in water-related issues and employ people from various disciplines, many of whom may influence decision-making in managing water resources. Each brings specific knowledge and experience to the table.

By definition, when water is scarce, there is not enough to satisfy everyone's needs. This inevitably brings conflicting demands for water from different sectors, making it an area ripe for misunderstanding and dispute over allocations. In such circumstances, it is vital that everyone understands and appreciates the needs of others, recognizes and agrees on priority allocations and knows when to compromise and negotiate trade-offs. Setting policy and decision-making in the water sector has become immensely challenging and complex, requiring knowledge and understanding of biophysical and socioeconomic systems and processes. This is the essence of IWRM, which is at the heart of the 2030 Agenda and SDG 6 (see Section 2.9).

This chapter offers a starting point for individuals who are relatively new to water resources management and would like to understand better and appreciate how others view water resources. We describe the roles of some key professionals involved in water resources planning and management and what water means to them: hydrologists, water resources planners, river engineers, freshwater ecologists, water engineers (supply and wastewater) and irrigation engineers, working in both developed and developing worlds.

Those already involved and perhaps focused on one aspect of water management may also find it helpful to dip into those water sectors with which they may be less familiar but which may impact on their decision-making. It may also benefit those who indirectly influence decision-making as water users to appreciate how others use water and avoid misunderstandings that can and have led to inappropriate plans with serious financial consequences (Perry & Steduto 2017).

2.1 The hydrologist's story

The water story begins with hydrologists' work and a focus on how much freshwater is available: the supply side of the supply and demand balance sheet. Hydrologists study water's natural state, origins and movement throughout the Earth.

2.1.1 The hydrological cycle

The science of hydrology is all about the elements that make up the hydrological cycle (Figure 2.1), which begins when moisture evaporates from oceans and lakes, and winds carry it over land and sea, where it falls as rain or snow. On the land, some 70 per cent of the rainfall goes back into the atmosphere as it evaporates from rivers and lakes and transpires from forests, pastures and crops. The rest finds its way overland into rivers or infiltrates underground into aquifers and eventually ends up in the oceans again. All these elements are quantifiable and, together, they provide a water balance where inflow equals outflow (this is the physical law of continuity, which says that what goes into a system must come out):

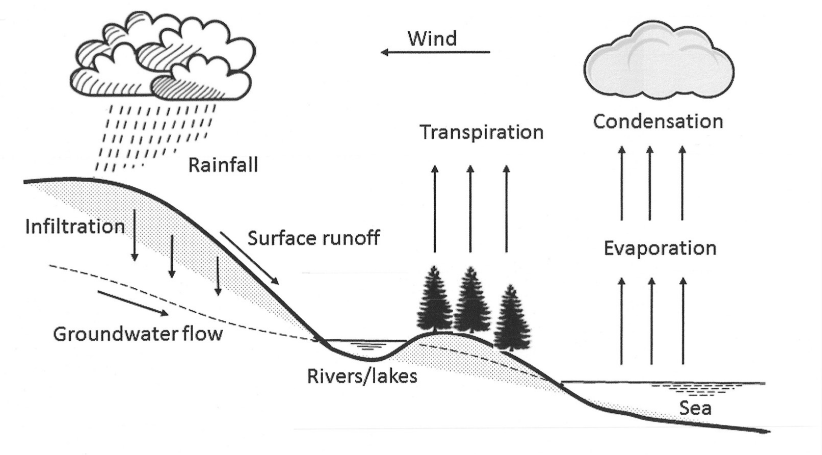

Figure 2.1 Hydrological cycle
Source: Kay (2017).

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> Inflow (rainfall) = outflow (from evaporation, transpiration, rivers, groundwater) + rate of increase/decrease in storage (in dams, soil water, wetlands, groundwater)

Hydrology is a relatively new science and has grown from being a side topic associated with civil engineering hydraulics into a sophisticated science in its own right, supporting water resources planning by assessing water availability. Good planning requires long-term climate data, particularly rainfall and temperature. Indeed, without accurate measurements, there can be no understanding of the routes taken by water within the hydrological cycle.

Many countries still have networks of meteorological stations set up in the twentieth century and even earlier. However, growing concerns exist that some are no longer adequately maintained and monitored regularly, especially in developing countries. There are horror stories about those who collect data guessing values once they become familiar with rainfall trends rather than reading gauges daily. Some European countries have records from hundreds of years, enabling them to identify severe rainfall, flooding and drought periods and how often they occur. The British navy has kept meticulous records of rainfall and temperature worldwide dating to the era of sailing ships in the eighteenth and nineteenth centuries. Indeed, early sea-temperature measurements indicated a general rise in sea temperatures, providing early indications of global warming. Such observations are vital for engineers designing flood protection and building reservoirs to avoid the consequences of severe droughts. The private sector is also becoming more conscious of water scarcity threatening the sustainability of their businesses, and they embrace "water stewardship" schemes and collect data to secure water for production to sustain their supply chains and markets. In some countries, there is also a growing interest in "citizen science", where individuals regularly monitor weather conditions, particularly daily rainfall and temperature, and make their data publicly available.

Unfortunately, today, few governments have the resources, time and, possibly, the inclination to reinstate lost meteorological stations. However, data are essential for planning, so some are now looking to smart technologies such as automation and remote sensing to help overcome data shortages. However, these are not without problems. They need "ground-truthing" to ensure accuracy, regular maintenance and protection from vandalism and theft (UN-Water 2018).

2.1.2 "Easy" and "difficult" hydrology

Some hydrologists like to talk about "easy" and "difficult" hydrology. They are not referring to the mathematics of hydrology but, rather, to the ease or difficulty of coping with extreme flood and drought risks in different parts of the world. "Easy" hydrology refers to places where annual rainfall is reliable, primarily within 15–20 per cent of the long-term average and of modest intensities. This situation occurs across much of Europe and in countries wealthy enough to engineer their way out of most water problems. Infrastructure can cope with the most likely flood and drought events in such circumstances and at an affordable cost. However, climate change is beginning to challenge these assumptions.

In contrast, "difficult" hydrology refers to places where rainfall is seasonal, unreliable and intensive, like the monsoon rains, and can vary by more than 40–50 per cent of the long-term average. River levels can rise rapidly, washing away bridges and over-topping dams. Designing hydraulic infrastructure for such conditions is fraught with difficulties and often unaffordable. Such extremes regularly occur in most developing countries across Africa and South Asia. A notable example is the Kariba Dam in the Zambezi River basin between Zimbabwe and Zambia, which suffered a major and costly setback during construction in the 1960s. Two successive floods, the second reported to be a 1 in 10,000-year event with flows up to 16,000 m^3/second, destroyed the early foundation work and killed many workers, leaving contractors to begin again once the flood subsided.

Interestingly, there are signs that Europe's "easy" hydrology is becoming more like the "difficult" hydrology experienced in countries with more extreme climates, as climate change brings more extreme floods and droughts. This signals a significant shift in how European countries must plan for the future. Scenario planning is one approach where planners develop different future options rather than relying on past rainfall records. This depends on a process of "back-casting", beginning with identifying a particular outcome or "end-state" of interest for the specific domain under investigation. Socioeconomic, climatic, biophysical, institutional, cultural and policy dynamics are then detailed, which may lead from the current situation to the end-state (Vergragt & Quist 2011).

2.1.3 Climate change increases uncertainty

Climate change is most visible in its effects on water resources: droughts, floods and melting glaciers and ice caps. Such changes undoubtedly affect future supply–demand balances and are difficult to quantify accurately. Separating natural from human-induced changes in our climate is also a complicated

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