1. Water and Cities

The Molecule

Water is remarkable. It is an odourless, tasteless and transparent molecule. Consisting of two hydrogen atoms bonded to a single oxygen atom, with each water molecule weakly connected to its neighbour, water is a relatively sticky liquid, with a high boiling point compared to other species of molecule of a similar atomic mass. Liquid water forms a solvent, solute and reactant that channels life. As far as we know, biological reactions do not occur in the absence of water. Barring new supplies delivered in the form of comets (an extremely infrequent occurrence fortunately), the amount of water on earth remains constant.[1]

Blue Planet

We inhabit a watery blue planet. When viewed from space, the oceans give our only home its blue colour. Earth is predominantly blue, but also white – with the white caps of the polar ice and the swirling white clouds organized into weather systems. Water, whether seen by astronauts, or viewed by the earthbound, may appear to be abundant, however it constitutes, in effect, a thin film on the surface of the planet. If the water of the earth, all 1.386 million cubic kilometres of it, were to be put into a single drop, it would create a sphere only 1384 km in diameter. To put this in context, the diameter of the earth is 12,742 km.

The Water Sensitive City, First Edition. Gary Grant.

For a sense of scale, compare a marble (equivalent to the volume of all the water of the earth) with a basketball (equivalent to the volume of the earth). The saltwater of the oceans makes up 96.5% of the total reservoir of water, the rest being groundwater, vapour, rivers, lakes and ice. Most freshwater, about 24 million cubic kilometres of it, is locked up in glaciers and ice caps. 10.5 million cubic kilometres of freshwater occurs as groundwater, with less than 200,000 km^3 of water in lakes, rivers and wetlands. Readily available liquid freshwater in rivers and lakes totals 93,113 km^3 and could be contained in a sphere just 56.2 km in diameter.[2] Only about 2.5% of the earth's water is suitable for human consumption without some kind of treatment. Water is ubiquitous in the biosphere; yet clean, safe, drinkable, freshwater is a relatively scarce resource.

A Global Water Cycle

Water moves and changes state as part of a perpetual planetary hydrological cycle. Radiation from the sun, striking the earth as it revolves, heats seas, lakes, soil and vegetation, causing water to evaporate. The sun also drives plant transpiration, the process whereby water passes through plants and exits via the leaves. As night turns to day and parts of the earth turn to face the sun, the warming water vapour forms into clouds. These clouds then move through the atmosphere in a process known as advection. When the temperature of the air falls, as it meets colder air, or as it cools when it rises, the water in clouds condenses and falls as rain, sleet or snow. As day turns to night and the dark side of the earth cools, dew may form (often the only source of water for the denizens of the desert). Where snow falls onto ice caps and glaciers it may accumulate and be sequestrated for millennia. Spring melt, by contrast may come from snow that has lain for no more than a few days, weeks or months. Rain falls back to the oceans or onto the land. It may be intercepted by vegetation, never reaching the ground, or may infiltrate into the soil. Surplus rainfall forms surface or underground flows, entering lakes, streams and rivers, with the latter usually reaching the oceans. Where soil is saturated or frozen, or where soil or rocks are impermeable, rainfall will form runoff and enter water courses. In locations where the geological conditions are suitable, where the rocks are permeable, water replenishes aquifers, where in some cases, like the water of the ice caps, it may remain for millennia – the so-called fossil waters.[3]

Terrain and Water

Topography, geology and biomes[4] have strong influences over where water collects and flows. High ground stimulates clouds to produce rainfall as the clouds are pushed upwards into colder air by prevailing winds. The leeward sides of mountains may receive less rainfall and are therefore said to fall within rain shadows. The land divides along watersheds into river basins or catchments, where rain and snow melt feed particular river systems, forests and wetlands. Small catchments have small rivers and cannot support large settlements by themselves. Large rivers, like the Nile, Indus, Tigris, Euphrates and Yellow River, carry silt that was the foundation of agricultural systems that supported the first cities and civilizations. Humans continue to modify the water cycle and those modifications have been increasing in extent and intensity, particularly since the middle of the twentieth century. There are particular problems with those places where people are exploiting the upper parts of catchments, intercepting or diverting freshwater that would otherwise supply communities downstream, a problem that is predicted to lead to an increase in conflict and even warfare between nations.[5] In addition, poor management practices, for example, deforestation in the upper reaches of river basins or an overreliance on piped drainage, can also lead to flooding and pollution problems downstream. Integrated catchment (river basin) management is frequently and quite rightly promoted as best practice but is usually applied in an inadequate and unsatisfactory way because of administrative and political divisions, conflicting private and public interests

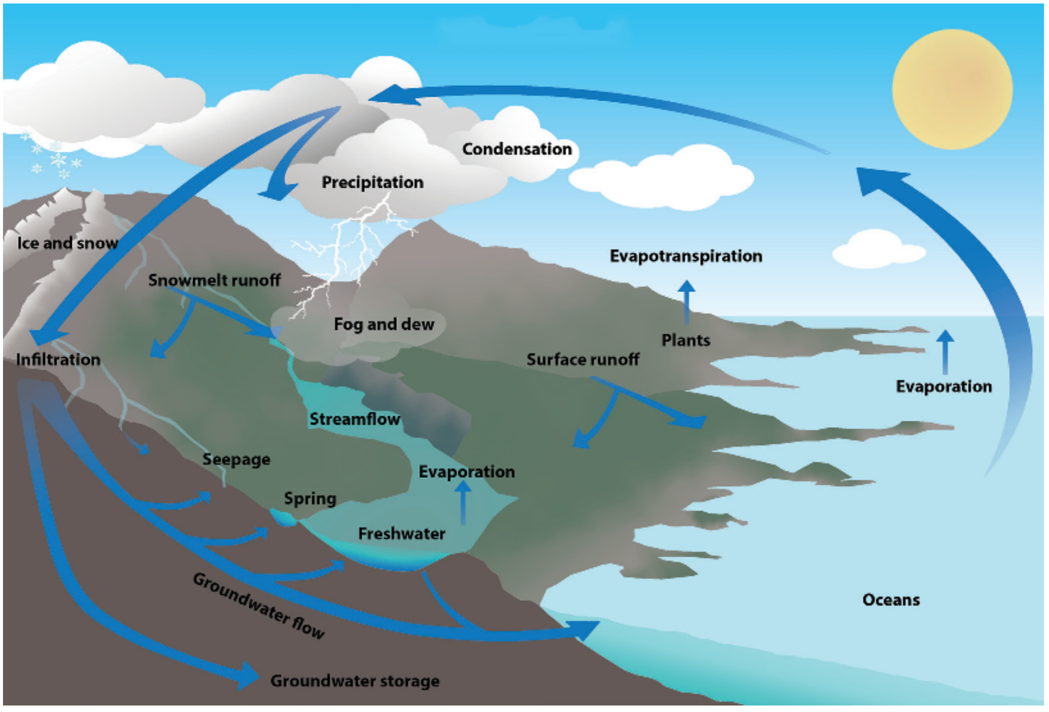

Figure 1.1 The water cycle. Based on an original by USGS. Illustration by Marianna Magklara.

or just plain ignorance. Watersheds (also known as river basins or catchments) would make the ideal administrative boundaries, but catchments frequently traverse administrative, political and even national boundaries, making comprehensive integrated catchment management plans difficult to agree and implement.

Seasons and Cycles

The 23.5° tilt of the earth's axis results in the northern hemisphere being more exposed to the sun from May to July and the southern hemisphere being more exposed to the sun from November to January. These annual changes bring the colder and wetter weather of winter to temperate regions and the wet (monsoon) seasons in the tropics. There is a larger landmass and therefore more plant biomass in the northern hemisphere, which means that the global atmospheric carbon dioxide concentration fluctuates, falling during the northern summer as plants grow and absorb carbon dioxide and increasing again through the northern winter as plant growth slows and, in some cases, halts. The current overall trend of atmospheric carbon dioxide concentration, of course, is up – largely the result of the burning of fossil fuels. The oceans play a key role in modifying the climate because they absorb and store heat. Ocean temperatures affect atmospheric temperatures, oceans currents and wind and the Pacific Ocean, which is the largest ocean by far, has the strongest impact of global weather patterns, as demonstrated by the El Nino phenomenon, which causes floods and drought across the Americas and as far afield as Australia, Southeast Asia and Africa.[6] Seasonal effects mean that rainfall in most parts of the world is uneven, with many regions experiencing intense rainfall for short periods followed by extended dry spells.

Variations in Rainfall

The amount of rain that falls varies considerably from region to region and place to place. For example, the heaviest rains of more than 11,000 mm per year occur where monsoon clouds meet the Kharsi Hills on the slopes of the eastern Himalayas in north-east India. Vancouver, on the rainy northwest Pacific coast of North America, enjoys more than 1100 mm of rainfall per year. London, England, to the surprise of many, is relatively dry, receiving only 600 mm of precipitation per year and Cairo, the capital of Egypt, receives just 25 mm of rainfall each year.[7] Rainfall patterns can be unpredictable. Even places noted for their reliable rainy season, like Ecuador for example, can suffer drought. In 2009, during an El Nino event, that country suffered its worst drought for 40 years.[8] As a result of the drought, reservoirs dried up, leading to water shortages in the cities, however much of the news at the time was dominated by stories of power blackouts, caused because of the lack of water to drive the turbines of the country's hydroelectric power stations.[9]

Changing Climates

As climate changes, so does the water cycle; 25,000 years ago, during the last ice age, sea levels were 120 m lower than at present, with more water locked up in the polar ice caps and mountain glaciers. The Ice Age climate of that time was drier and rainfall was lower overall than it is at present. Rainforests shrank in size and deserts and grasslands expanded.[10] As global temperatures warmed after the end of the last Ice Age, the atmosphere increased its capacity to hold water vapour, in turn changing weather patterns, which then allowed both tropical and temperate forests to expand in area. Anthropogenic (man-made) climate change is accelerating the process of warming, with the ice caps and mountain glaciers shrinking still further and sea levels rising. The atmosphere is predicted to carry even more water, bringing more unsettled weather with heavier downpours, more powerful storms and longer droughts. (Read more on climate and climate change in Chapter 5.)

Atmospheric Carbon Dioxide

There has been increase in atmospheric carbon dioxide caused by deforestation, agricultural intensification and expansion and, more recently, the burning of fossil fuels (an increase from 280 parts per million in the year 1800 to 400 parts per million in 2015).[11] This has had indirect effects on the water cycle but there have also been direct impacts. Deforestation, which usually leads to the creation of new pastures or croplands, tends to dry out soils and the landscape as a whole. Following deforestation, there are increases in surface runoff and therefore overall reductions in the volume of water evaporated and reductions in quantities of ground water. Regional patterns of cloud formation, and therefore rainfall, also change. Once denuded of forest vegetation, soils lose some of their organic matter and associated capacity to store water. The problem is further exacerbated as wetlands are also drained to create farmland. Then the farmland itself is drained. When this occurs, organic matter is oxidized and carbon dioxide is released into the atmosphere. Where crops, which require large quantities of water, are introduced, irrigation often becomes necessary, resulting in the unsustainable exploitation of groundwater or overabstraction of water from rivers. Globally, around 70% of the water abstracted from rivers, wells and boreholes is used for agriculture.[12] Lake-fed rivers (like, for example, the Aral Sea) shrink or may disappear altogether as the result of abstraction of water for agricultural use.[13] Excessive irrigation in arid climates may also result in increased soil salinity, which can inhibit plant growth and lead to a significant reduction the range of crop species that may be grown. In some cases land may be abandoned as the result of salinification.[14]

Fossil Fuels and Growth

Fossil fuels powered the Industrial Revolution. The world's population grew steadily from a billion in 1800 to 2 billion in 1920 – unprecedented growth, in effect powered by coal – however, even more dramatic change came with the onset of the Oil Age, with an increase in population from 2 billion to 7 billion people during the 90 years between 1920 and 2010. The global population is still growing and is predicted to peak at around 9 or 10 billion by 2050, a further increase of 2 to 3 billion. Global population growth has also been a story of urbanization and mechanization. The Industrial Revolution reduced the demand for farm labour as agriculture became increasingly mechanized. There was also a demand for labour to man the new factories, a demand that also drove the migration of people from countryside to town. This, in turn, caused towns and cities to grow rapidly – a process that still continues in developing countries. The population of Manchester, an industrialized city in the northwest of England, for example, grew from around 330,000 in 1800 to more than 2.5 million people in 1920. The population of Rio de Janeiro in Brazil increased from about 500,000 in 1900 to its current level of more than 6 million, with similar numbers of people in the immediate hinterland. These increases in city populations have been repeated and are still being repeated all over the world, so that now more than 50% of the world's population lives in urban areas. In developed countries the vast majority of the population is already urban. This trend looks set to continue, perhaps until after the global population peaks later this century. Across the world, on average, 5 million people move to cities every month. Water demand thereby increases – water for the agriculture that feeds the populations of the cities and water to supply the people in their dwellings and places of work. Increases in incomes change lifestyles, with more bathing and an increase in ownership of water-consuming equipment and processes. (See Chapter 3 for more information on why the demand for freshwater is increasing.)

The Ancients and Water

The first city dwellers relied on springs or wells for most of their supplies of potable water, but would often supplement this with rainwater collected from roofs and subsequently directed into purpose-built cisterns (storage tanks). For example, large cisterns holding 50 m^3 or more, dating back to the second millennium BC, have been described from Minoan sites.[15] Per capita water use was low during this period and sizeable communities of tens of thousands could be supported in this way; however, as cities grew still further, water needed to be brought from further afield. The ancient Romans, for example, who numbered in total approximately 1 million people, constructed a series of aqueducts to bring water from distant upland springs and streams.[16] This trend, of bringing water to cities from increasingly distant upland locations, has continued and accelerated to the present day. The combination of more urban dwellers, each consuming more water, means that growing volumes of high-quality freshwater water need to be directed to cities, drying out the upper sections of river catchments and polluting the lower sections of rivers and coastal seas.

Dams

Rivers are dammed, sometimes many times, to create reservoirs for irrigation and drinking water but also for the generation of electricity using hydro-electric power stations. Dams are nearly always constructed before the affected aquatic ecosystems are properly described and the full spectrum of ecological impacts is fully understood. Dams block the migration of fish, including some species like salmon, which spawn in the shallow fast-flowing streams that are often occur upstream of dams. Another major consequence of dam building is that sediments are trapped behind the dam, rendering them no longer available to replenish and fertilize floodplains, wetlands and deltas in the lower reaches. These lowland and estuarine features may then shrink in places where they once accreted. There are now unprecedented demands for water and water-supply and treatment equipment and there are increasing strains on freshwater water supplies, which in certain arid locations, are already insufficient to meet demands. In the United States, for example, between 1950 and 2000, a period when the population increased by 80%, the volume of water extracted by municipal water departments for both homes and businesses increased by 300%.[17] During that time the population grew, but people were also getting used to using larger quantities of relatively inexpensive water. More recently, since the mid-1990s, there have been the first efforts to reduce per capita consumption. Population, however, still grows. (There is more on the history of water supply and sanitation in Chapter 2. Chapter 4 describes how cities are supplied with water.)

Limits

There is a commonly encountered attitude and expectation that municipal water companies and utility companies can always find a way to bring water to where it is needed. In a certain sense that is correct – with sufficient investment, equipment, infrastructure and expenditure of money and energy it is usually possible to import freshwater or treat salty or tainted water. Even when conventional sources of water from rivers and aquifers are exhausted or unavailable, canals, tunnels and pipelines can be constructed to move water across great distances, or sea water can be made fresh in desalination plants. Foul water can be treated and recycled. There are problems, however: construction, operational and maintenance costs continue to rise and there are losses of biodiversity even in the more remote areas from where water is often abstracted. Dirty water costs much more to purify than the relatively clean water that emerges from underground aquifers or steadily trickles from forested slopes into upland lakes. The emerging problem for those wishing to rely on conventional energy-intensive approaches to supplying and treating water is that the long-term trend for energy prices has been for these to increase – a trend that is likely to continue, despite occasional dips in price like that associated with the current (but temporary) 'tight oil' boom in North America. Electricity prices vary considerably from country to country; however, broadly speaking, prices have followed those of fossil fuels, which tripled between 2000 and 2010. As well as the overall increase, during that period there was also the price spike and crash of 2008–9, which has added an element of uncertainty, making planning even more problematic. Some commentators are now convinced that cheap fuel has returned for good, but most geologists will point out that the supply of oil cannot continue indefinitely. Electricity generation itself, as well as being required to pump water, also requires water for cooling, with an estimated 15% of all water extracted from the environment being used by power stations.[18] Energy is needed to supply water and water needed to supply energy – the so-called energy-water nexus.[19]

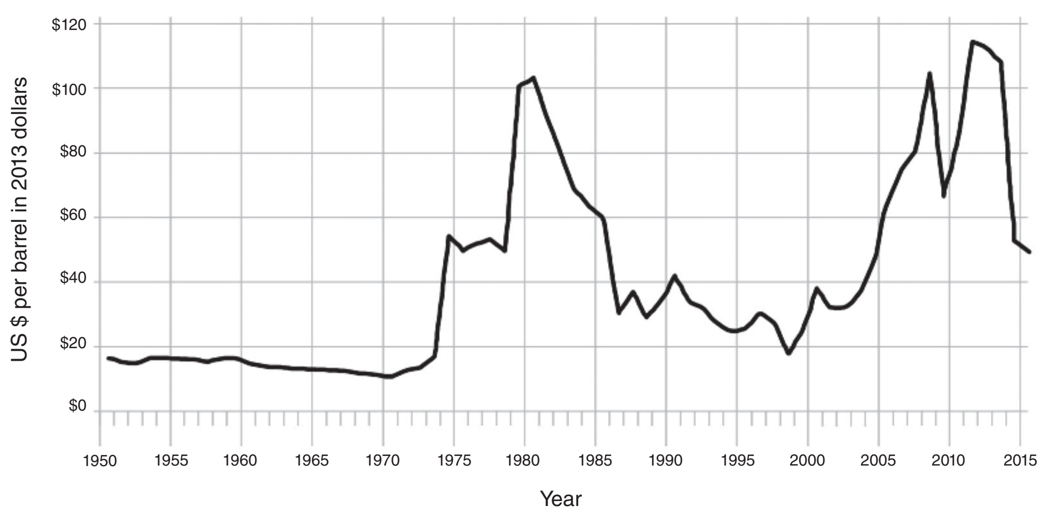

Figure 1.2 Oil prices 1950–2015.

Sanitation

The authorities usually move quickly to ensure that utility companies send sufficient quantities of drinking water to cities, even if the provision is unsatisfactory in some way – after all, we cannot live without it – however, it usually takes much longer for adequate sanitation to be provided (sometimes centuries). For example, the New River,[20] an artificial waterway designed to bring drinking water to London, was opened in 1613, but it wasn't until the 1860s, following the 'Great Stink' of 1858, more than two centuries later, that sewers were installed to divert raw sewage away from the centre of the city.[21] A few decades later, in 1900, sewage treatment finally commenced, nearly three centuries after piped supplies were installed.[22] The result of those works was that London never again suffered major outbreaks of the deadly waterborne disease of cholera. In many cities, especially in informal or squatter settlements, people still do not have access to a toilet and in the majority of cities sewage still continues to enter watercourses without any form of treatment. A third of the global urban population, about 1 billion people, has inadequate access to sanitation, resulting in the premature and avoidable deaths of more than 2 million city dwellers each year (that is equivalent to more than 5,000 people each day).[23]

Pollution

Sewage entering the wider environment is not only a threat to human health but it also causes severe damage to ecosystems. Faeces can smother aquatic fauna and, as bacteria break down the excess organic material, there is a decrease in dissolved oxygen, leading to the death of fish and most species of invertebrates. Even modest increases in dissolved nitrates and phosphates from sewage may cause eutrophication, leading to algal blooms and the subsequent dieoffs and decay, which cause those low levels of dissolved oxygen. The most badly affected watercourses can become devoid of wildlife, apart from a few pollution-tolerant mud-dwelling invertebrates like midge (Chironomid) larvae and tubifex worms. Although water quality in rivers in some of the developed countries has been improving for a few decades, following the installation of treatment plants and the closure and transfer of factories overseas, water quality in most of the world's rivers and estuaries continues to decline. The problem has spread to coastal waters with several hundred hypoxic or 'dead zones' now recorded close to many of the world's major population centres.[24] As suggested by the name, 'dead zones' no longer support fisheries. Many of these polluted coastal zones have also lost the capacity to function as spawning grounds for fish that spend part of their life cycle offshore.

Many formerly important inshore fisheries are now closed and those fishermen continuing to seek their living from fishing are often now having to sail far away from their home ports (sometimes to another hemisphere) to find fishing grounds with sufficient stocks to fill their ever larger nets and keep their floating factories occupied.

Urban Drainage

Where agricultural land has been replaced by the sealed surfaces of conurbations (mainly roofs and roads), the characteristics of surface water runoff change for the worse. Urban drainage tends to rely on pipes that discharge water into watercourses with great speed, with the water carrying with it pollutants, which in turn damage aquatic ecosystems. Urban storm water, the excess rainwater that runs off of roofs and paved areas, is typically directed through gutters and downpipes directly into underground drains. Most storm-water drains include grilles to catch litter and chambers that intercept silt and oil (but not all pollutants). Water is then directed into pipes, normally laid on a gentle gradient, ultimately sending the polluted water to a watercourse. This has the desirable effect of drying out the surface of streets rapidly but it causes large volumes of water to enter watercourses in a short period, where silt is deposited and pollutants discharged. Small watercourses suffering from such flashy flows tend to be lined with masonry or concrete to prevent erosion and, as they become more dangerous and unpleasant, over the years they tend to be covered over to become underground culverts, forgotten between maintenance visits and largely devoid of life. Quite large streams have been lost underground in this way and larger urban rivers put into deep concrete channels with trapezoidal cross-sections. A notable example of the latter is the Los Angeles River, often no more than a trickle but a watercourse that grows rapidly into a torrent following a winter storm. Storm water also causes problems in older cities with so- called combined sewers, where surface water drains are interconnected with foul sewers.[25] When rainfall is heavy, sewers leading to treatment works can be overwhelmed with rainwater, resulting in the discharge of raw sewage through overflows, which leads to sewage entering watercourses and, in severe cases, may even cause sewage to back up and flow out of the drains and into the streets. New developments do not combine foul and storm-water drainage; however, legislation designed to protect rivers from pollution means that many municipalities and utility companies in North America and Europe are investing billions of dollars and euros respectively into the retrofit of tunnels, retention basins and other projects designed to alleviate or eliminate the problems caused by combined sewer systems. Now there is increasing interest in Low Impact Development[26] or Sustainable Drainage Systems,[27] which mimic natural drainage by intercepting, detaining, attenuating and infiltrating rainwater and promoting evapotranspiration through the use of natural features, thereby keeping rainwater out of the sewers. (Read more on near-natural or sustainable drainage systems in Chapter 7.)

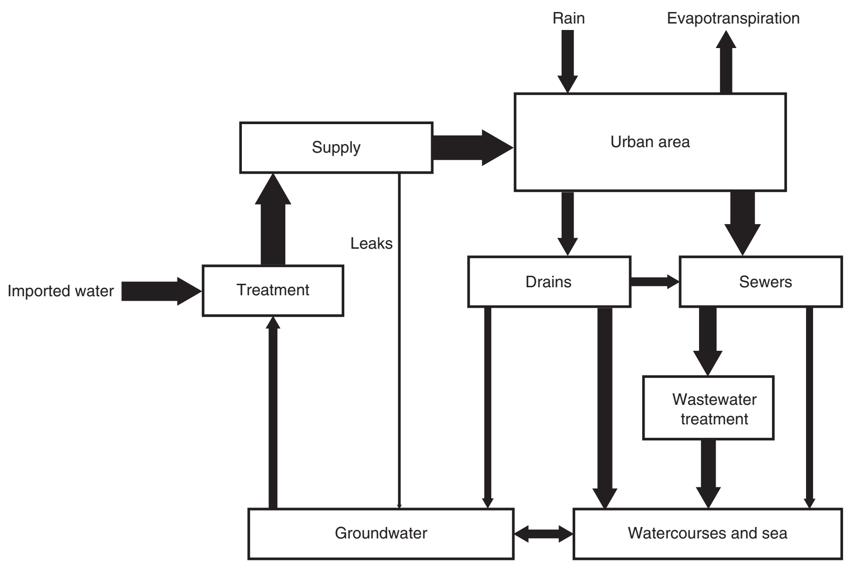

Figure 1.3 The urban water cycle. Illustration by Marianna Magklara.

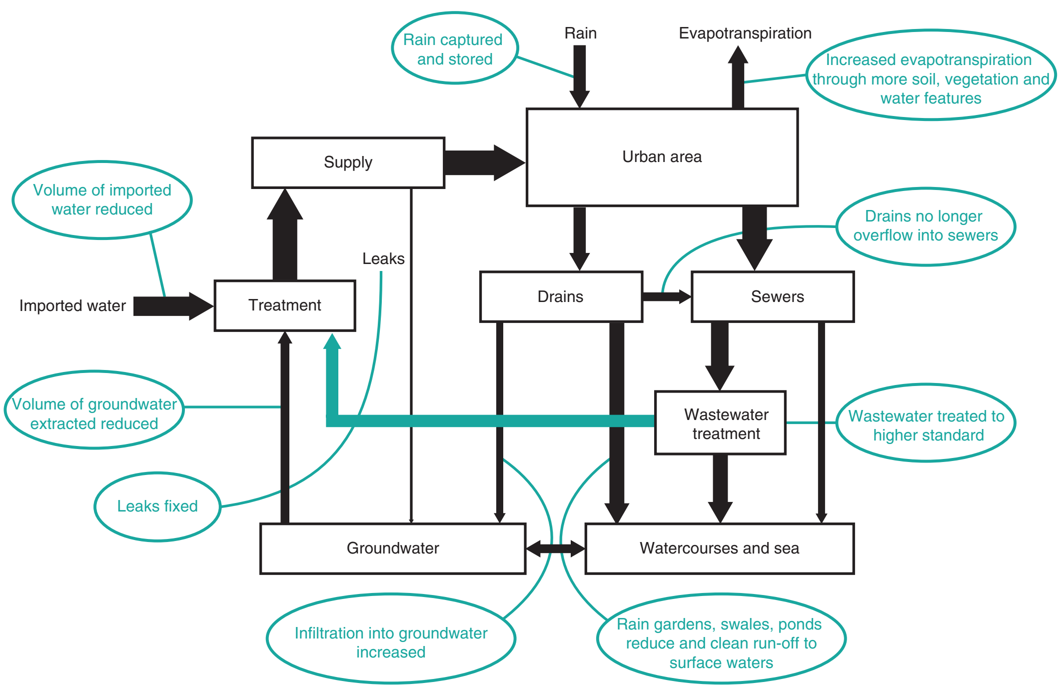

Figure 1.4 The sustainable urban water cycle. Illustration by Marianna Magklara.

Potable Water

The reliable supply of potable water that is distributed to every street, home and business in developed countries may be taken for granted by most of us who live in those places. Although taken for granted, piped supplies of potable water truly enrich the lives of those who enjoy this facility, improving health and saving time. These remarkable systems, however, have been provided at a cost to the wider environment. The assumption by consumers that there will be a constant high-quality uninterrupted supply of potable water means that, without a second thought, people install and use extra bathrooms, showers, washing machines, power washers and irrigation systems that significantly increase consumption. Water consumption in some affluent countries, for example, like the United States and Australia, exceeds 500 litres per person per day. Compare this with a typical less-developed country, where the figure for per capita daily consumption can be as little as 50 litres.[28] Water piped into homes in developed countries is usually safe to drink, which requires expensive treatment, yet very little of the water which flows into people's homes passes their lips. In the United Kingdom, typically a third of that exceptionally clean water is used for toilet flushing (although this figure is lower in most other Western European countries) and another quarter for showering and bathing.[29] There is also concern over the waste of water when people run taps whilst they are cleaning their teeth or washing vegetables (a running tap wastes around 6 litres every minute). Most of the potable water that flows into homes is subsequently wasted and, especially since the 1990s, there have been campaigns to address the problem following the realization that increasing supply may not always be affordable or feasible in the future. Residential water consumption is metered in most developed countries, however there are a few exceptions (for example, in the United Kingdom only 40% of homes have water meters installed). The metering of water is useful. It assists with the identification of leaks and has been shown to reduce consumption by 10%.[30] In many cities, concerted efforts have been made over an extended period to reduce demand for domestic water using economic incentives (for example, charging for heavy use) as well as subsidising water-saving equipment and gadgets. In addition there have been many initiatives to sponsor information campaigns designed to change attitudes and behaviour.

Waste

Another major cause of waste in urban water supply systems is leakage within the distribution network – a problem that varies considerably in extent between cities and nations. Losses of water from within the water distribution network in Germany are less than 10%. By comparison, in Albania, losses were once reported to be as high as 75%.[31] Losses occur through corrosion, leaky joints, damaged valves and faulty hydrants and pipe breakages. Repairs are expensive – it is often perceived as cheaper to increase supplies to compensate for losses rather than to repair an underground leak; however, attitudes are changing. Most suppliers now have programmes of testing for and monitoring of leaks and are beginning to appreciate the benefits of initiating repairs at an earlier stage. Of course, broken and corroded pipework must eventually be replaced if it is to continue to perform to a satisfactory standard, that is, a standard where adequate water pressures are to be maintained. As well as affecting supplies, burst water mains can cause serious flooding to properties and may require street closures whilst repairs are made, leading to travel delays and other costly disruptions. (Read more about how demand is being reduced in Chapter 8.)

Rainwater Harvesting

Falling rain is one of the cleanest sources of water. It can be contaminated by airborne pollution but is nearly always cleaner than river water. Where rainwater is harvested it is usually collected from roofs and is therefore more likely to be close to the homes or businesses where it is required. The technologies required for harvesting rainwater are relatively simple and the technique has been used for millennia, ever since cities were first established. There are a few problems associated with rainwater harvesting – roofs can be contaminated with bird droppings and other pollutants and if water is not carefully stored it can be spoiled by algal growth or invaded by aquatic microbes (including some pathogens) and invertebrates that lay their eggs in water (notably mosquitoes and midges) – however, problems can be overcome easily through the adoption of simple safeguards. Storage tanks represent the most significant cost of rainwater harvesting (usually around 90%), although overall the cost of rainwater harvesting, when compared to the cost of securing other water sources from further afield, is relatively low. The capacity of rainwater harvesting systems is largely determined by the availability of a suitable collection area (often a roof or another clean, impermeable surface), rainfall patterns, the likely duration of dry periods between rainfall events, consumption rates and the volume provided of storage tanks. Rainwater harvesting in certain rural locations, like Gansu Province in China, for example, is well established; however, rainwater harvesting in most modern cities has been largely abandoned and forgotten since the advent of reliable water supply networks in the period following the Industrial Revolution. There is now a renewed interest in the rainwater harvesting, however. There have been thousands of schemes implemented in Germany, for example, and new associations of practising and aspiring rainwater harvesting companies are springing up all over the developed and developing world.[32] (To read more about how cities are harvesting rainwater see Chapter 9.)

Recycling

Once used, water can be captured, cleaned and recycled. The easiest source of water to exploit in this way is greywater (sometimes known as sullage), that is, water that has been recently been used for baths, showers and washing.[33] Greywater usually contains soap and detergents that can be easily screened and filtered using proven and affordable technology. As long as premises are occupied, there is a reliable and predictable stream of greywater (in contrast to rainwater), with typically a quarter of the potable supply to a building being subsequently available as greywater. The collection of grey water requires changes to the typical plumbing system, with the wastepipes from sinks, baths and showers connected to filtration systems and storage tanks. In some jurisdictions, regulations originally devised to minimize the risk of contamination of potable water by wastewater mean that the use of greywater is prohibited. In addition people in some cultures are squeamish regarding the suggestion that waste water is recycled. Water that carries sewage, so-called blackwater, can be treated to a quality whereby it is suitable for reintroduction into the potable water supply system. In most situations sewage is treated to a level whereby it is safe to discharge into rivers or the sea without an immediate threat to human health but in countries where water is becoming scarce or where there is a dependency of water imported at considerable cost from other jurisdictions, there is a strong interest in recycling sewage and treating it to a high standard. Singapore, for example, where the government wants to reduce the amount of water imported from Malaysia, is using microfiltration, reverse osmosis and ultraviolet light to turn sewage into drinking water as part of its NEWater Programme.[34] (For more on the recycling of urban water see Chapter 10.)

Biodiversity

Extinction of species is a natural process; however, conservation biologists have become alarmed by the current accelerated rate of extinction, said to be more than a thousand times the earlier 'background' rate. These extinctions are closely associated with habitat loss and overexploitation of ecosystems, which has increased in parallel with population growth during the twentieth century. The United Nations' Millennium Ecosystem Assessment, published in 2005, estimated that between 10 and 30% of all mammalian, bird and amphibian species are threatened with extinction due to human activity.[35] This loss of biodiversity is a major threat to civilization because when species are lost and genetic diversity eroded, ecosystems become degraded or may even collapse, leading in turn to the loss of the ecosystem goods and services (including food, wood, fibre, air and water purification and climate regulation) that we all depend on. The biodiversity of aquatic inland ecosystems, including rivers and lakes, has been particularly badly affected by urbanization. Wetlands have been drained to create more agriculture to feed to burgeoning urban populations. For example, 73% of the marshes of northern Greece have been drained since 1930, resulting in a decline in their associated flora and fauna, including wildfowl. Globally, more than 40% of all rivers are now intercepted by dams, which have had a severe impact on fish migration patterns and breeding success. Modifications of rivers have resulted in the loss of habitat features, which has compounded these problems, leading to the collapse of most inland fisheries. Many endemic fish species are threatened, and inland aquatic ecosystems are being lost even before biologists have had a chance to describe them. Most lowland aquatic ecosystems worldwide have been severely degraded or even destroyed in many cases.[36] Extinct species are lost forever and many of the little known and poorly understood subtleties and complexities of ecosystems can never be recovered once damage and degradation has occurred.

Restoration

River and stream restoration is possible and desirable. Reducing the volume of water abstracted from the wider environment will help to reduce our reliance on dams and will allow watercourses and associated species to recover once dams are removed. It is also possible to restore watercourses and surface water features in urban areas, helping to restore the connections between upstream and estuary and thereby making cities better places to live. The movement towards sustainable drainage systems or low impact development (as described in Chapter 7) has tended to emphasize the issue of flood management, however it constitutes a real opportunity to create wildlife habitat and restore biodiversity in the grey urban deserts and canyons that many of us inhabit. The water-sensitive city can reduce its impact on the wider environment; however, the water-sensitive city should also be a biodiverse city. Watercourses can be reinstated and naturalized for the purposes of restoring biodiversity and terrestrial features modified to intercept, infiltrate, evaporate and store water can also be habitats planted with native species in natural associations and plants known to benefit wildlife. This represents an opportunity to restore biodiversity in towns and cities, where most of humanity lives and works.

The Future

I predict that the citizens of the future water-sensitive city will see more water and will enjoy more interaction with water. Once water is brought to the surface and kept out of pipes, designers can find ways of celebrating the flows and forms of, intermittent, usually trickling, but occasionally cascading, water. This can be ornamental and playful but also practical. People, especially children, love to play with water. Water stirs our curiosity and fascinates us. It stimulates experimentation and stimulates the imagination. Playing with water encourages us to communicate and interact and is suitable for everyone regardless of age, gender, culture or ability. On a hot day, there are few activities more enjoyable than splashing around in clean, cool, clear and fresh water. Rainwater that has been carefully stored and appropriately treated can be safely used for play and outdoor water features. Having more soil and water available will also help the citizens of the water-sensitive city to grow more of their own food. Recent initiatives in France, China, the United States and even the Gaza Strip have demonstrated how urbanites can grow food on underused corners, roofs and even walls in the most difficult circumstances.[37] There are some highly technical ways of doing this, with pipework and automation; however, even a simple planted pot watered by hand can be productive and a means of escaping the worries of the world for a few moments each day. The hands-on, volunteer-led approach to urban greening may also extend from private spaces into the public realm. As local authority budgets are cut, volunteers are filling the gaps. Take, for example, the roadside rain gardens created and managed by citizens in Portland, Oregon. When bureaucrats block urban greening initiatives, guerrilla gardeners may make the plantings, if necessary, under the cover of darkness.[38] Eventually embarrassed officials relent and allow more volunteer involvement or, if that is too difficult, may then improve their own efforts at urban greening.

Privatization and Regulation

It is assumed by many of us that the provision of water and the treatment of wastewater is little more than a commercial matter, a problem to be solved by the private sector, eager to satisfy its customers by providing an excellent product or service, with government regulation ensuring that strict standards are met. The neoliberal economists who first suggested the privatization of utilities and the politicians who enthusiastically pursued this agenda, were most interested in the narrow agenda of economic growth and efficiency, lower taxation and the weakening of worker organizations, rather than more important issues of integrated catchment management, water conservation, water-quality improvements, reducing the production of greenhouses gases, tackling climate change or halting biodiversity losses. Public water supply and sanitation authorities were first privatized in the United Kingdom in 1989 and organizations like the World Bank are still enthusiastically promoting various forms of privatization, including public-private partnerships, where full privatization is perceived by local people to be an unacceptable change. The privatization of water supply and sanitation services is still controversial. Currently close to a billion people receive their water from privately owned corporations. Where they are well established, those who are ideologically committed to privatization will, no doubt, insist that the private sector will continue to play its key role in the water cycle of the future; however, it is clear that there are a number of problems with the current model. Little accountability, a lack of transparency, few opportunities for citizen participation and inflexibility and spiralling costs are common complaints. Authorities must retain an independent regulatory role and this has significant establishment and running costs. Regulation can effectively maintain high water quality and set limits on price increases; however, private utility companies will inevitably be more concerned with their own profits and asset values, rather than general concerns over scarcity, lower water quality, the drying of the wider landscape, losses of ecosystem services or biodiversity. There is also a problem with new concerns related to climate change not being addressed because these issues have usually been outside of the scope of the commercial agreements struck between corporations and governments. If private corporations do continue to provide water, drainage and sanitation, contracts may need to be rewritten to allow more flexibility to promote stronger efforts to bring about more climate change mitigation and adaptation, as well as the conservation of biodiversity and the restoration of ecosystem services.

Coordination and Cooperation

There is a growing consensus that if the security of water supply and levels of sanitation that protect both human health and restore the aquatic environment is to be achieved, more will need to be done by all of us. This requirement goes beyond the city limits or the piped network of the water supply and treatment companies. Comprehensive plans will be required that integrate water use within whole catchments. This will require new levels of cooperation between interest groups, landowners, agencies and administrations – not only within regions and nations but also, on occasion, between nations. Land-use management plans will need to be linked with river basin/ catchment management plans. The passage of water through the managed landscape will need to be modified in ways that consider water quality, biodiversity, flooding, energy and water supply. There will also need to be great efforts made to collect, recycle and reuse water in urban areas, with an increased effort to make processes more water efficient and people more committed to the conservation of water. The measurement and monitoring of water will need to be improved. Data will need to be shared and used to inform decision making, with water infrastructure systems monitored in real time as an integrated operation within the 'smart cities' of the future.[39] The 'smart cities' will need to become part of 'smart catchments'. Water management will need to become more flexible to enable us to deal with the vagaries of the weather, a problem that is predicted to become worse with climate change.

Towards a Better Future

Whatever the direction chosen by politicians, businessmen and citizens, it seems likely that the forces associated with climate change, population growth and water and energy shortages will transform cities and their hinterlands. Although these changes are unprecedented and will surely bring pain, there are also some reasons for hope. Waste and inefficiencies can be tackled and ecosystems can be restored. People are able and willing to identify strategies and techniques for creating a water-sensitive civilization. Some cities are already embracing a holistic approach to urban water management. A good examples are the Australian cities, which have promoted the concept of Water Sensitive Urban Design (WSUD), whereby the city optimizes the whole urban water cycle including stormwater, wastewater and groundwater management along with water supply, processes that are usually considered in isolation and are the responsibility of many different organizations regulated by a wide variety of different statutes and bodies.[40] (Chapter 14, the final chapter, looks at how the water-sensitive city of the future might look and function.)