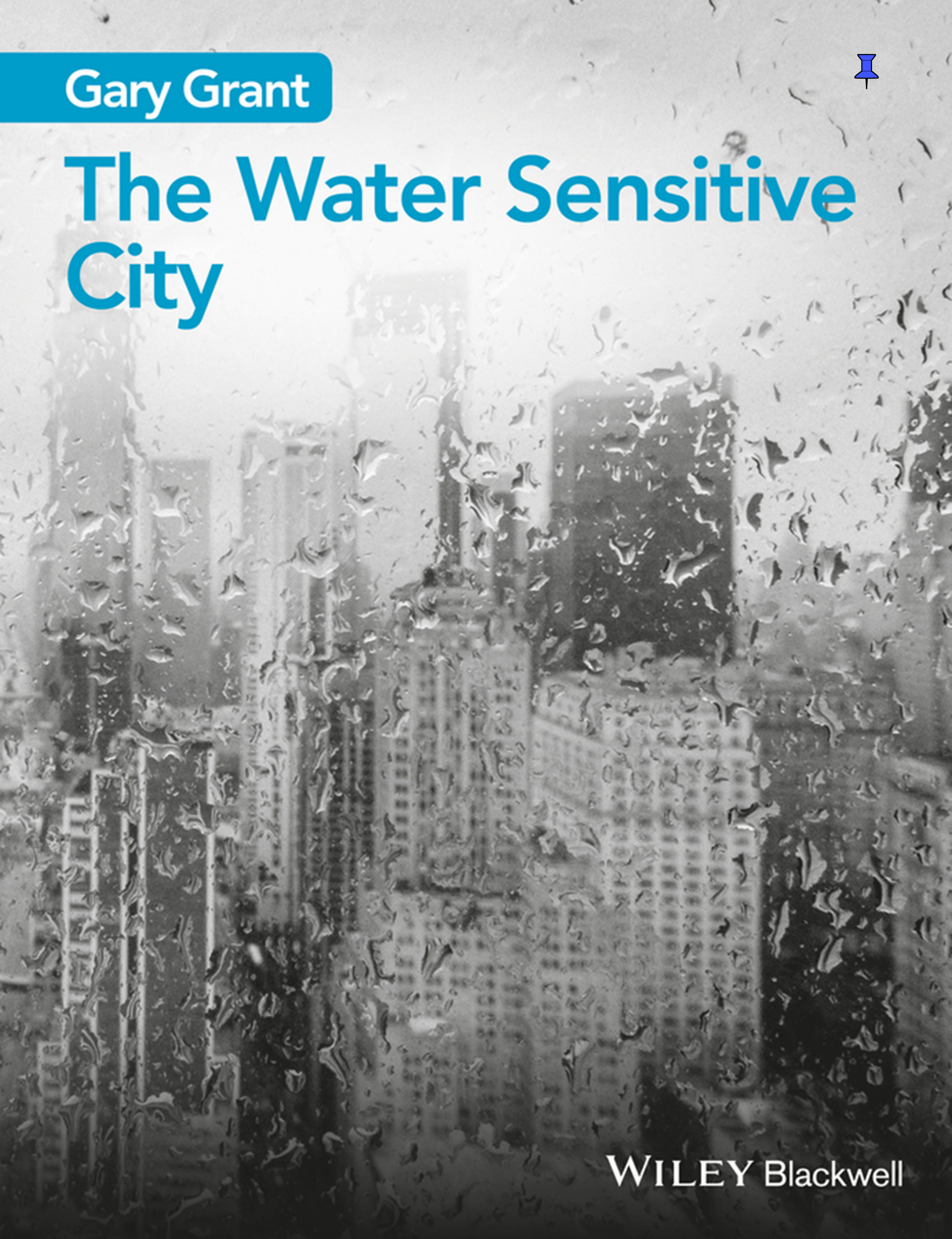
Gary Grant

The Water Sensitive City



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About the Author

Gary Grant is a Chartered Environmentalist, Fellow of the Chartered Institute of Ecology and Environmental Management, thesis tutor at the Bartlett Faculty of the Built Environment, University College London and Director of the Green Infrastructure Consultancy (formerly the Green Roof Consultancy). In 2006 he wrote *Green Roofs and Facades* published by BRE Press and in 2012, *Ecosystem Services Come to Town – Greening Cities by Working with Nature*, published by Wiley-Blackwell. From 2006 to 2009 he was a director of EDAW and then AECOM Design + Planning, where he worked on large-scale planning projects including the London 2012 Olympic Park, the Bedford Valley River Park, the Whitehill-Bordon eco-town, Education City, Qatar and Saadiyat Island, Abu Dhabi. More recently, with the Green Infrastructure Consultancy, he has been working on planning and design, including green infrastructure networks for cities, green roofs, living walls and rain gardens.

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I would like to thank my wife Sue for her support and understanding during the writing of this book.

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

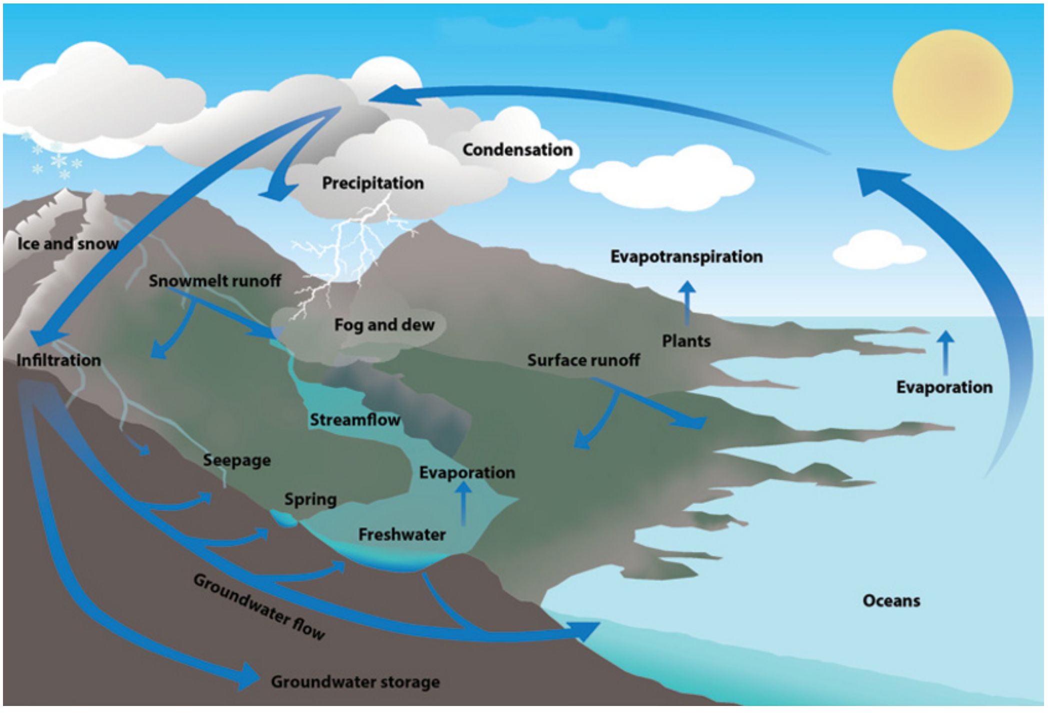

Figure 1.1 The water cycle. Based on an original by USGS. Illustration by Marianna Magklara.

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