Chapter 22
Global Water Security: Engineering the Future

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Abstract The paper introduces some of the general challenges of global water security, particularly in poverty stricken regions such as Africa, and highlights the likely global impact of climate change, increasing pollution and population growth etc. on water resources, as outlined in recent studies. The nexus between water, food and energy is introduced, along with the concept of virtual water and the impact of the water footprint and the need for society, industry and governments to become more conscious of the water footprint, alongside the carbon footprint. Various practical solutions to enhancing security of supply are introduced and discussed, such as desalination and integrated water management in the form of 'Cloud to Coast', together with global actions needed. Finally, some water security challenges and opportunities for developed countries, such as the UK, are discussed, particularly with regard to the need to price water appropriately and the need to appreciate that the price of water should cover more than just the cost of delivery to the home. The paper concludes with the urgent need to raise the profile of global water security at all levels of society and through international bodies, for the benefit of humanity worldwide.

Keywords Climate change • Water resources • Water pollution • World population • Integrated water management • Eco-systems • Bio-diversity • Desalination • Water pricing

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22.1 Introduction

In recent years there has been growing international concern about the increasing crisis in Global Water Security, with security referring here to security of supply – both quantity and quality. As an example of this concern in April 2010 the Royal Academy of Engineering published a report entitled Global Water Security – An Engineering Perspective [1]. This report was produced by the UK Institution of Civil Engineers, the Royal Academy of Engineering and the Chartered Institution of Water and Environmental Management, through a Steering Group of 12 specialists working in the field. The Group took evidence from a wide range of international experts covering all aspects of water security. The main drivers for the report were concerns from numerous sources from within the UK Government, the professions and learned societies about the increasing challenges arising relating to water security and the implications for the UK, both nationally and internationally. Some of these challenges, threats and opportunities are introduced below.

The world consists of 1.4 billion km^3 of water, of which only 35 million km^3 are available in the form of freshwater, and of this resource only 105 thousand km^3 are accessible as a vital natural resource. This vital resource is required for a wide range of uses including: sustaining human life (i.e. consumption and sanitation), supporting for food production (with the addition of nutrients and sunlight), supporting energy production, sustaining industry, and maintaining our ecosystem, biodiversity and landscape.

There are 1.2 billion people living on this earth today with no access to safe drinking water; typically two million people die annually of diarrhoea – still one of the biggest causes of infant mortality on our planet today [2]. Traditional public health engineering still offers considerable challenges and rewarding career opportunities, second to none, to those young people aspiring to want to save lives or improve the quality of life of our fellow citizens living in developing countries and facing challenges of inadequate and/or poor quality water resources.

There are 2.4 billion people who do not have basic water sanitation and typically one million die annually of hepatitis A. Women in developing countries have to walk typically 3.7 miles to carry water for the family [3]; again engineers can, and do, make a huge contribution to the quality of life for these women. Floods often cause significant loss of life and destroy homes, with last year's floods in Pakistan leading to an estimated 21 million people being homeless. However, the disease associated with the after effects of such floods can often bring far more loss of life to communities and countries than the floods themselves [4]. It is estimated by the BMJ 2004 that at any one time more than half the hospital beds worldwide are occupied by people with water related diseases [5]. Other interesting – but startling – facts relating to water security include such information as: 'more people in the world have access to cell phones than have access to a toilet' [6]. Hence, the challenges of water security are immense and on a global scale.

22.2 Impacts of Climate Change and Population Growth

Water is at the heart of climate change and, along with the challenges cited above, global water security is expected to be exacerbated through shifting weather patterns, more intense hurricanes, typhoons, storms, floods, droughts, and the effects of glacial melt, snowmelt, evaporation, evapotranspiration and rising sea levels. Mean precipitation is expected to increase in the tropics and high latitudes, and decrease in the sub-tropics and mid-latitudes [1]. Water stress will deteriorate globally over the next century, with increased runoff in certain parts of the world (East Africa, India, China) and reductions in other regions (Mediterranean, North Africa) causing increasing problems. Average global temperatures are expected to rise by at least 2°C by the end of this century. If the temperature increases between 2°C and 5°C there will be major water resources problems globally, also resulting in significant sea water level rise and causing catastrophic coastal flooding in many parts of the world, such as Bangladesh. The implications of significant average global temperature rises above 2°C are highlighted in the Stern Report to the UK Government [7].

In 2009 the UK Government's Chief Scientific Advisor, Professor Sir John Beddington, raised the prospect of a "Perfect Storm" of global dimensions by 2030 with the impacts of global challenges such as climate change, food, energy and water security coming together to impact significantly on the lives of all people on earth. He noted that if we don't act now this will put at risk the wellbeing of many people on earth, especially the world's poor and most vulnerable. By 2030 the world's population is expected to increase from six to eight billion. Associated with this population growth we can expect the demand for food, energy and water to increase by 50% for food, 50% for energy and 30% for water (Fig. 22.1).

The water-food-energy nexus is crucial to our existence, with water being at the heart of everything; it is crucial for our energy supply, food, health, industry, trade etc. If we look at the water stress globally (defined as millions of litres of water available per person per year) from 1960 to 2010, we find that even in the southeast of England water supply is currently particularly stressed, and water stress is a growing major problem across right across the US.

Problems in water supply will relate not only to the 50% increase in human population over the next 30 years but also to urbanisation that is occurring all over the world, which is exacerbating this effect. In countries such as China, for example, people are moving into the major cities creating more mega-cities, while in the UK people are moving more and more to the southeast of England, which is not sustainable over the long term and we have to look at how we can make other parts of the UK more attractive for regional development in the future. Projects such as the Severn Barrage, previously considered as a project only for renewable energy, need to be considered also as creating a catalyst for re-distributing the population and encouraging people to live in parts of the country where the water stress is much lower [8].

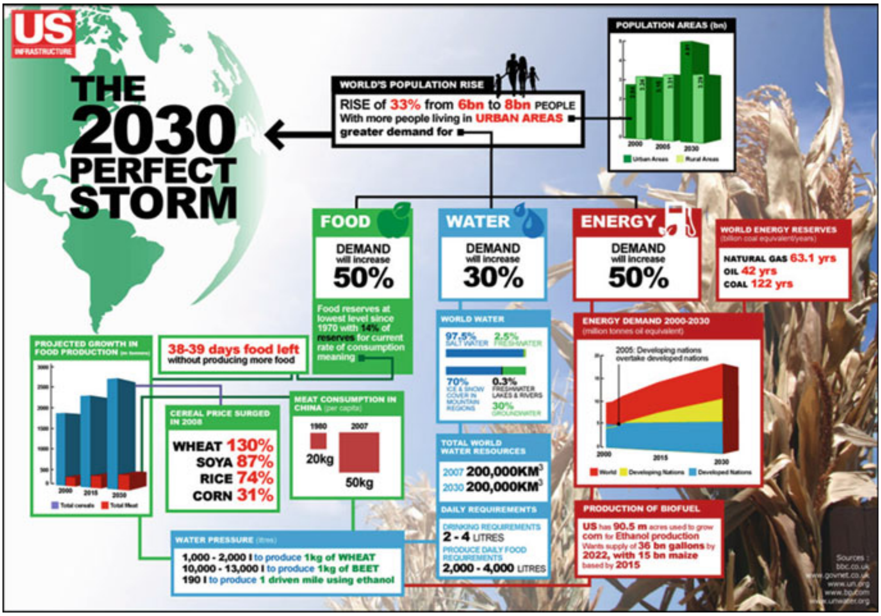

Fig. 22.1 The 'Perfect Storm' from a lecture by Sir John Beddington UK Government Chief Scientist (Source: US Infrastructure)

22.3 Water as the Vital Resource

As indicated above, increasing attention is now being paid to water as a vital resource in the context of the **water-food-energy nexus.** For example, water is required to grow food that sustains life; energy is required to treat and move water; energy production and industrial processes require fresh water; lifestyle changes result in increased energy and food consumption; increasing conflicts are arising between land for bio-fuels and land for traditional agriculture; etc. Impacting on all areas of the nexus we have: competition for finance; international trade flows; the environment and loss of biodiversity; climate change impacts on supply and demand; etc.

The percentage of water that is used globally for domestic, industrial and agricultural purposes is typically 8%, 23% and 69% respectively, with these figures varying from 13%, 54% and 33% across Europe, to 7%, 5% and 88% across Africa. Even though 13% of water abstractions in Europe are for drinking, the largest withdrawals are for irrigated agriculture and for food production. There is limited scope to increase the global area for crop irrigation, therefore there is a growing need for higher crop yields or improved irrigation to meet future food demand. Alternatively, we need to seek to grow more food in those parts of the world where there is sufficient land and rainfall. Furthermore, there is a growing need to produce food in such a way as to protect the natural resources it depends on, i.e. the soil, nutrients and water; particularly since we also depend upon these resources for other services, such as: drinking water, climate regulation, flood protection, filtering of pollutants etc.

22.4 Understanding the Problem

In the first instance we have to recognise the water cycle in providing freshwater in the form of rainfall, evaporation, condensation, precipitation, infiltration and run-off. In considering the 'Cloud to Coast' concept, being developed by Halcrow and Cardiff [9] where water transport solutions are being treated in an integrated manner, we note that for every 100 raindrops that fall on the land only 36 reach the ocean. Of the rest, most are held as soil moisture (referred to as 'green water') and which are used by our landscape, ecosystem and farmers. The role of green water is much undervalued and constitutes two thirds of our rainfall. That which enters lakes, rivers and aquifers (referred to as 'blue water') provides the water which we withdraw for our needs. It is this water that receives most attention. Finally there is grey water, which is the wastewater and surplus water which is returned to rivers etc. following consumption (Fig. 22.2).

Finally, there is the concept of virtual water. This is the water which has been used to grow food or produce goods, for domestic purposes or export, depending on the local or national economy. It may have green, blue and grey water components. Virtual water leads into the concept of the water footprint, which is analogous to that of the carbon footprint. To produce 1 kg of wheat requires 1,300 l of water [10], whereas to produce 1 kg of beef requires 15,000 l of water, i.e. over ten times as much water. Looking at other commodities, it takes 140 l of virtual (or embedded)

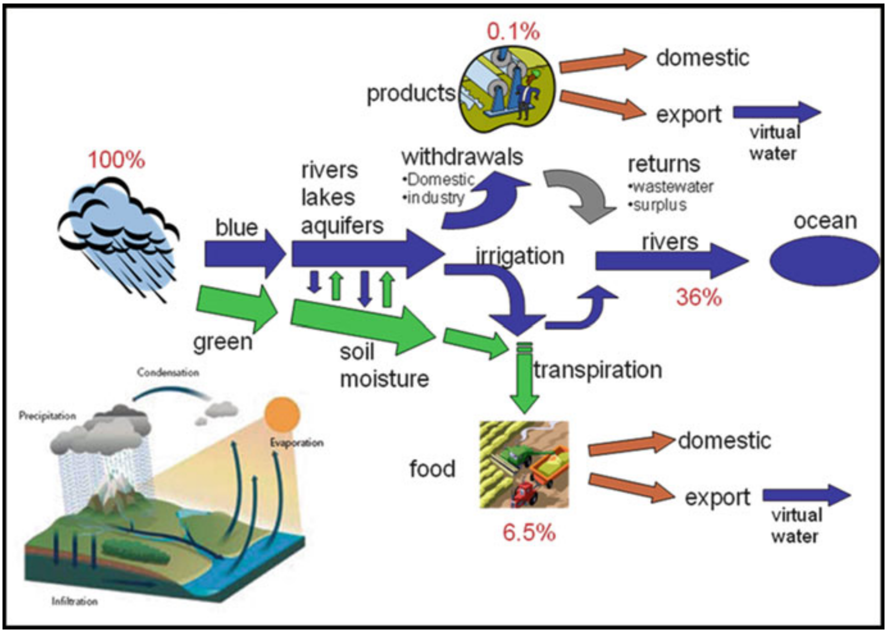

Fig. 22.2 The water cycle: including *green* water, *blue* water, *grey* water. (Source [1])

water, nearly a bath full (150 l), to produce one cup of coffee, and that water is often used in another country – such as Brazil – when the coffee is drunk in a country in Europe. One pair of cotton jeans requires 73 baths full of virtual water, which are attributable mainly to the cotton production, and that water is likely to be used in countries such as Egypt, where there are already serious water shortages.

The water footprint can be expressed in many ways; by person, nation, industry or product. Applied to nations, the concept permits assessment of external and internal footprints, often closely linked to trade. Taking the UK as an example, the average footprint of a person is estimated to be 4.3 m^3 per day, of which only 150 l, i.e. 1/30th, is that which is used in homes supplied by water companies for domestic use. The remainder is the virtual water embedded in the food eaten, the beverages drunk, the clothes worn, the cars driven, etc. Currently water footprints focus almost exclusively on volume and this approach is an excellent tool for raising awareness, but it does not necessarily represent the impacts of water use. To achieve this there is also a need to consider water stress and quality.

The embedded water footprint of the 25 European Union countries bears most heavily on India and Pakistan, which are the primary sources of cotton supply to the EU. The drying up of the Aral Sea is one example which can be partly attributed to cotton production, though this is not the only cause of the drying up of this water body. The point to appreciate, however, is that the demand for embedded water products in one country can have very serious impacts elsewhere in the world, such as Egypt, for example. International trade has the potential to save water globally if a water intensive commodity is traded from an area where it is produced with high productivity to an area with lower productivity. However, there is a continuing lack of correlation between countries hydrologically best suited to growing food or crops such as cotton and those that actually do. Furthermore, as economies of countries such as China and India continue to grow, then changing food diets and the increasing demand for clothes and material goods such as cars etc., will place an added stress on global water security, partly through the increasing imports of virtual water.

22.5 Developing Potential Solutions

Desalination is one possible solution in large coastal cities, but this process is still relatively expensive and imposes a large carbon footprint through large energy demands. Research studies being undertaken within our Hydro-environmental Research Centre at Cardiff University have also found that salinity levels can accumulate along the coastal region and this cannot be sustainable in the long term. Computational fluid dynamics simulation studies along the Arabian coast of the Persian Gulf have predicted increasing salinity levels along the coast due to the rapid growth in desalination plants in the region and this must have long term impacts for the hydro-ecology of this highly stressed water body. Field data and ecological observations confirm these numerical model predictions [11].

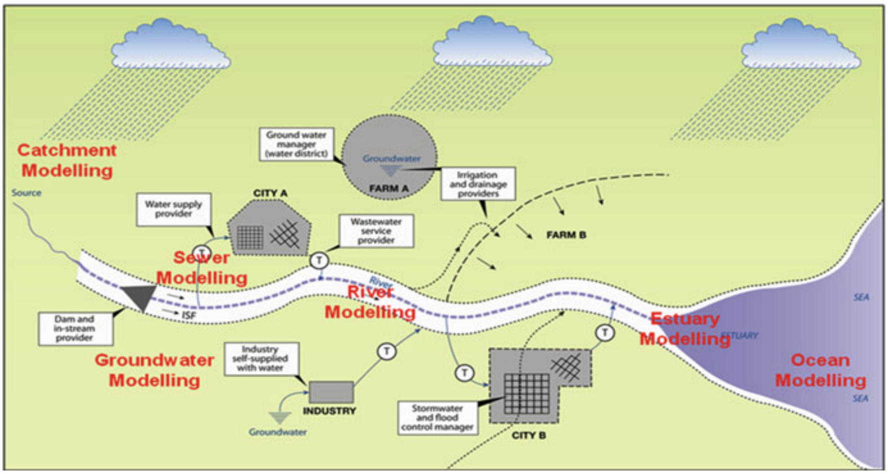

Fig. 22.3 C2C cloud to coast: integrated water management solutions

Conservation and water re-use is often a short term solution to a longer term problem. Storage involves water transfer and better integrated water management, with a much more holistic approach to river basin management being required than used hitherto. To increase global water security, improved water quality in river basins and estuarine and coastal waters is required, along with a reduction in global water pollution. It also goes without saying that global population growth needs controlling. Integrated water management requires a Cloud to Coast (C2C) approach that treats the water cycle with an integrated systems solution, bringing together the professionals who currently specialise in modelling various components of the system. They include hydraulic engineers, hydrologists, biologists and the like, with the distribution from the cloud to the coast, through the catchment, groundwater, sewers, rivers, estuaries, needing to be treated as one. The Hydro-environmental Research Centre at Cardiff University is currently refining su1ch an integrated approach with the Halcrow Group Ltd., wherein complex numerical hydro-environmental modelling tools are linked through open MI to provide integrated solutions with mass and momentum conservation at the boundary interface etc. (Fig. 22.3) [12].

Turning to the value of water, this poses the question: Is water a human right or is it an economic good? Economic theory informs us that it is easier to encourage funding if the true economic value of water is realised. Without it we get a price-cost differential and long-term sustainability becomes unlikely. However, to what extent is water a human right and, if so, whose responsibility is it to deliver it and meet the costs? True water pricing and trading is rare, but Australia and Chile have introduced it in their water scarce regions and they maintain that it has resulted in lower water consumption and significant increases in agricultural productivity. In the UK the average cost of water per cubic metre is £3 ($4.8), paid to the private water companies. This provides the consumer with approximately 1 week of water for drinking, washing, cooking, toilet flushing, car washing and in some places garden watering. This is not expensive in comparison with what else one could buy in the street for £3, including: a sandwich, 2 l of bottled water, a Starbucks coffee, a pint of beer, etc. These comparisons place the price of water into context and one must question whether the cost of water is really so expensive that the price could not be raised in the UK? If we continue to undervalue this precious resource we will not be able to face some of the challenges that our world faces today.

Ecosystems control the character of renewable freshwater resources for human well-being by regulating how precipitation is partitioned into evaporative, recharge and runoff processes. These so-called ecosystem services are categorised as: (i) provisioning services, which include controlling water quantity and quality for consumptive use; (ii) regulatory services, which include buffering of flood flows and climate regulation; (iii) cultural services, which include recreation and tourism; and (iv) support services, which include, for example, nutrient cycling and ecosystem resilience to climate change. Society generally doesn't measure or manage economic values exchanged other than through markets. The invisibility of nature's flow into the economy is a significant reason behind ecosystem degradation.

Forests and wetlands play roles in determining the level of local and regional rainfall, the ability of the land to absorb and retain water, and its quality when used. Avoiding greenhouse gas emissions by conserving forests is estimated to be worth $3.7 trillion.

In returning to the challenge of achieving Global Water Security, we believe there are five tests that need to be satisfied to achieve this goal including,

- Affordable drinking water supplies for all, to promote public health
- Sustainable sources of water for industry and its supply chain, to promote economic health
- Integrated management of water resources (including quantity and quality), for all users
- Policy and trade reforms, which encourage sustainable water resources development and which discourage conflict, and
- Mobilisation of substantial volumes of public and private funding, via transparent and fair regulatory regimes in order to fairly price water.

22.6 Conclusions

In conclusion, there are undeniable and understandable international concerns about the increasing threat of Global Water Security, in terms of the quantity and quality of water supply. These concerns need to be addressed at the international level by concerted actions, with these actions focusing on – but not exclusively – the following recommendations:

- An increasing awareness of the water-food-energy nexus and the inter-dependency of each of these resources on one another,

- The need for the water footprint and the concept of virtual water to be better understood and more widely used by: industry, governments and the public,
- Better technologies and practises are needed for more efficient agriculture, without detrimental effects on the aquatic ecosystem,
- New sustainable sources of water are needed from desalination plants (together with more energy efficiency), recycling and water harvesting,
- Water needs to be more fairly priced on the global trading markets, particularly with regard to pricing the cost of virtual water,
- Intergovernmental bodies, such as the World Trade Organisation, need to elevate issues of Global Water Security up their own and governmental agenda, and
- The Public must be more engaged to become more involved in the issues and challenges of Global Water Security.

Ultimately, water is one of the most precious resources on earth and man cannot live on this planet without this most precious of resources; for our very existence it needs to be available in quantity and of a sufficiently high quality.

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