Water policy in the UK
The challenges

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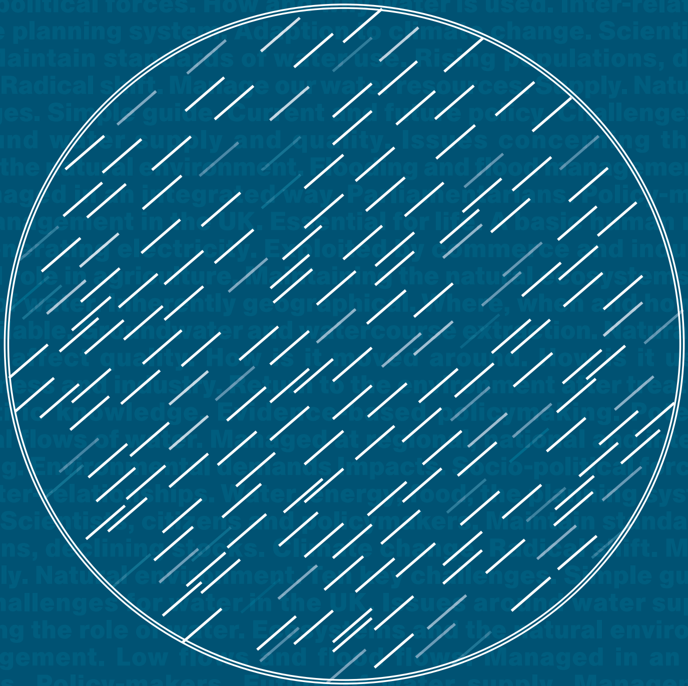

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This paper edited by Dr Steven Toole
Policy and Public Affairs Manager
Royal Geographical Society (with IBG)

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The evidence in this paper brings a geographical perspective to the debate on the current and future challenges for water policy in the UK.

Details are provided below of the key individuals who have contributed to the drafting of this policy document. Please note that any involvement should not be taken to indicate agreement with every statement or view expressed within.

- Professor Rick Battarbee, Environmental Change Research Centre, Department of Geography, University College London
- Professor Louise Heathwaite, Co-Director of the Centre for Sustainable Water Management in the Lancaster Environment Centre, Lancaster University
- Professor Stuart Lane, Faculté des geosciences et de l'environnement, Université de Lausanne
- Professor Adrian McDonald, School of Geography, University of Leeds
- Professor Malcolm Newson, Director, Tyne Rivers Trust and Emeritus Professor within Geography, Newcastle University
- Dr Heather Smith, Research Fellow in Water Governance, Cranfield University
- Dr Chad Staddon, Senior Lecturer in Human Geography, Geography and Environmental Management, University of the West of England
- Dr Geraldene Wharton, Reader in Physical Geography, School of Geography, Queen Mary, University of London

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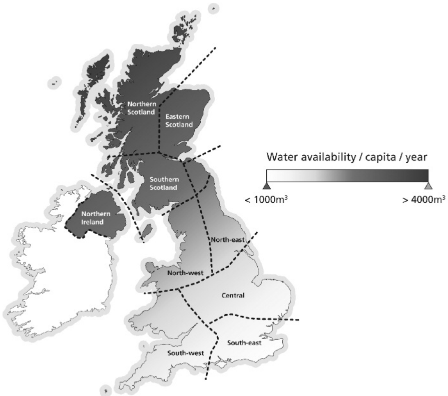
Introduction

Water is essential for life and a basic human need. It is vital to our way of living: generating electricity, exploited by commerce and industry, and used in our homes for cooking and cleaning. It is also essential for agricultural production as well as in maintaining the natural ecosystems upon which we, and all life, depends. Concerns regarding the clean and plentiful supply of water, its movement through and interaction with the physical environment, and human intervention with these processes, are inherently geographical. These range from where, when and how much rain falls, how much is available within groundwater and watercourses for extraction, to how natural landscapes and human land use practices affect its quality. There is also a clear geography behind how it is moved around and then used by individuals, agriculture, business and industry before return to the natural environment after appropriate treatment.

A geographical dimension to the evaluation of water issues has contributed much to the advancement of scientific knowledge and sound, evidence-based policymaking, and has the potential to provide further important insights, with a significant amount of research on a wide variety of relevant issues including:

- the ways in which physical flows of water (surface and ground waters) should be managed at regional, national and international scales
- water quality
- the role of land use planning
- environmental demands and impacts
- understanding the socio-political forces that shape how and why water is used
- inter-relationships between water, energy, food, and the planning system
- impacts of and adaption to climate change



Map of UK water availability per capita (Source: Staddon 2012)

Increasingly scientists, citizens and policymakers are asking if and how we can maintain current standards of water use in the context of rising populations, declining environmental stocks and the uncertainties of climate change, and whether we actually need a more radical shift as to how we use and manage our water resources, both for supply and in the natural environment.

Focusing on ten key challenges, this briefing from the Royal Geographical Society (with The Institute of British Geographers) is a simple guide to the current and future policy challenges for water supply management in the UK. The briefing covers issues around water supply and quality and issues concerning the important role of water in ecosystems and the natural environment. Though its scope does not extend to cover wider issues around flooding and flood management, it does consider how low flows and flood flows need to be managed in an integrated way. It is aimed at parliamentarians, policy-makers, and others with an interest in the future of water supply and management in the UK.

An obvious geography of water resources which should be factored into all discussions of sustainable water management in the UK is that some regions have water in abundance, whilst others experience frequent droughts. When local consumption is balanced against availability, water rich and water poor regions can be identified (Defra 2008; European Union 2011). The spatial distribution of rainfall in the UK mapped against population density is where the future water availability challenge lies.

In southern and eastern England, where rainfall and available water are comparatively low and population comparatively high, water use (both total, and as a percentage of water available for abstraction) tends to be higher (National Audit Office 2007). In some areas abstraction is already above its environmentally sustainable level (Defra 2008). On a world ranking of water availability – from most to least – southeast England would be 161st out of 180 world regions. Increasing population and housing growth will increase water demand by 5% or an extra 800 million litres of water per day by 2020 (Environment Agency 2009).

The UK has more than enough rainfall to supply current demand, but the problem lies in where it falls. Rainfall is much higher in less densely populated north and west. Proposed solutions to this geographically uneven distribution of available water takes many forms but have tended towards large-scale engineering solutions, like reservoir construction and pipeline networks to supply water over large distances (for example, reservoirs have been built in rural Wales since the nineteenth century to supply Birmingham and Liverpool). In 2010 a de-salinisation plant opened in Beckton, East London to extract drinking quality water from sea water at times of extreme drought.

One solution proposed suggests the UK should follow countries like Spain and develop a national grid to move water, essentially from the northwest to the southeast. Whilst the idea has an immediate logic, others believe that the idea would be disruptive, much more expensive than alternative measures, and would have a negative environmental impact, particularly from the carbon generated by pumping it across the country (Staddon 2010)(see Challenge Eight).

Although there are currently some water transfers between adjacent regions (essentially neighbouring water companies trading with each other, such as the Ely Ouse transfer scheme from Anglian Water to Essex and Suffolk Water) solutions may also be realised from local management measures such as water metering, other behavioural change and conservation measures, and reducing leakages, a concept of 'Managing Water Locally' (The Institution of Civil Engineers et al. 2011).

Much of the ground underneath our feet contains water. These aquifers[1] are mainly in the Midlands and southern England, contributing as much as two-thirds of domestic supply. Over abstraction[2] has led to falling river levels in many areas creating dangers for long term water supply. Other problems to emerge from over abstraction, particularly in coastal areas like Kent, include sea salt (saline) intrusion which damages water and soil quality and can negatively impact upon agricultural output. Recognising the geographically uneven distribution of water resources and consumption, the Environment Agency (EA) developed a strategy for managing water resources involving 104 spatially-defined resource zones in England and Wales. In a process called 'Restoring Sustainable Abstraction', abstraction limits on watercourses in England and Wales are being re-calibrated against the best current environmental science, which will mean many abstraction licence holders, particularly in the southeast, will see their allowances reduced (Environment Agency 2009).

[1] The technical term for a water-bearing rock.
[2] Abstraction can be used for many purposes other than water supply, including agriculture and energy generation.

In England and Wales there are 100 catchments as defined by the Environment Agency (EA) (2012a). A catchment is an area with several, often inter-connected water bodies (rivers, lakes, groundwater and coastal waters) where surface water from precipitation converges to a single point. There has been increased recognition in recent decades of the need to value and manage water issues in a more joined-up (also termed 'holistic' or 'integrated') way on a catchment scale (also known as a 'river basin') (Molle 2009; Newson 2009).

Integrated Water Resource Management (IWRM)[3] promotes reintegration of policy on land-water interactions. The approach looks to find a balance between changing (and uncertain) environmental pressures, such as climate change, and society's demand for water use (Newson 2009; Everard 2011). The approach became entrenched in policy when the European Union's Water Framework Directive (EU WFD) became law in December 2000 (European Union 2000). The UK's delivery on its obligations under this directive was signalled most strongly in the Department for Environment Food and Rural Affairs' White Paper, *Making Space for Water* (Defra 2005). In 2011 the department announced its intention to take forward a new catchment based approach to water abstraction management that focuses 'on the management of land and water in a co-ordinated and sustainable way to balance environmental, economic and social demands at a catchment scale'. The recent *Water for Life* White Paper (Defra 2011) also promotes a catchment-based approach for managing water resources.

Some commentators (Biswas 2003; 2004; Jeffrey and Geary 2006) argue the definition of IWRM remains too broad and that questions remain over how to make it workable in practice. For example, political agreement may be difficult where catchment and administrative boundaries do not align.

Pilot catchment partnerships have been established in 2011 and 2012 by Defra to test these new approaches. Ten are being hosted by the Environment Agency (EA) and a further 15 pilots by a range of organisations, including rivers trusts, wildlife trusts and the water industry. These pilots are to be evaluated with findings used to inform guidance for a national roll-out of the catchment-based approach across England and Wales from 2014 (Cascade Consulting 2012). Furthermore, 'Catchment Sensitive Farming' (CSF)[4] has been a joint project between the EA and Natural England, which has aimed to deliver targeted support to enable farmers and land managers to take voluntary action to reduce diffuse water pollution from agriculture (Natural England 2011). In Scotland CSF has been applied in practice through 'General Binding Rules' (Scottish Environment Protection Agency 2009a).

To date, few measures tackle water in catchments and we have therefore failed to take advantage of the natural processes (the 'ecosystem services') offered by land and freshwater systems to protect and harness catchment hydrology and regulate water quality through internal nutrient processing in rivers (Heathwaite 2010; Maltby 2012) (See Challenge Three). One such example of integrated working across a catchment is provided by natural flood management by slowing down runoff (through measures including contour ploughing, field edge uncultivated barriers, forestry debris dams, gully planting) (POST 2011) and by also 'Making Space for Water' (Defra 2005) on floodplains to store water. These measures both reduce flood peaks and improve resilience to drought conditions. This contrasts with the previous approach of getting rid of rainfall and runoff as fast as possible, which has made our catchments increasingly vulnerable to periods of low rainfall.

[3] Note, the most common definition comes from the Global Water Partnership (2000).
[4] Funded by Defra and the Rural Development Programme for England.

UK wetland resources are extensive with nearly 400,000 kilometres of rivers, around 6,000 lakes covering 2,000 square kilometres, nearly 1,000 square kilometres of floodplains and nearly 400,000 hectares of other wetlands including bogs, marshes and reed beds (see WWT survey of English Wetlands, Hume 2008). Yet these are unevenly distributed, with 90% of the volume and 70% of the surface area of the UK's freshwater in Scotland (UK National Ecosystem Assessment 2011).

Freshwater is a heavily exploited and highly managed natural resource delivering many different functions with benefits to both the natural environment and to human populations. Freshwater ecosystems, as well as housing unique and diverse biota, provide ecosystem goods (e.g. drinking water, fish, electricity) and services (e.g. detoxification and purification of water and nutrient cycling, flood mitigation, recreation) (Heathwaite 2010). The importance of healthy, functioning ecosystems has come very much to the fore in the last decade, as has the need to properly value ecosystems (Holt and Hattam 2009; UK National Ecosystem Assessment 2011), particularly following the United Nations (UN) Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) which recognises four categories of ecosystem service: 1) 'provisioning services' (ecosystem 'goods') comprising things that can be used or extracted to support human needs; 2) 'regulatory services', processes that regulate the natural environment such as air quality, climate, water flows and quality, diseases and pests; 3) 'cultural services' encompassing diverse aspects of aesthetic, spiritual and recreational values; and 4) 'supporting services' which may not be directly exploited but include processes essential to maintain the integrity, resilience and functioning of ecosystems.

The ecosystem services approach stresses the importance of understanding the interrelationships between 'hydrological, geomorphological and biological processes in water management rather than merely prioritising human-focused perspectives' (Jones 1997; Petts et al. 2006; Newson 2009; Everard 2011; Maltby and Acreman 2011). It also identifies new ways of tackling 'old' problems, as in the case of pollution caused by discharges from contaminated land or agricultural practices. It is now becoming more common practice to weigh up the costs and benefits for the ecosystem by taking different actions. For example, comparing local water treatment costs against those required to actually physically contain the source of pollution itself or altering local land management practices (perhaps through plants which remove pollutants known as bioremediators). In practice it is likely optimal outcomes will be obtained by combining of such strategies.

Implementation of the European Union's (EU) Water Framework Directive (WFD) (European Union 2000) is raising awareness of the broader value of ensuring aquatic ecosystems remain in 'good' status. Hence, the ecosystem service concept builds on the Millennium Ecosystem Assessment (Haines-Young and Potschin 2007) and now forms a central component of UK environmental management policy (Defra 2007; Scottish Government 2010). The culmination of this work was the publication of the UK National Ecosystem Assessment (2011). This report concludes that the terrestrial and aquatic ecosystems of the UK support a wealth of wildlife and contribute a range of services on which we ultimately depend, and which are worth billions of pounds to the UK economy. A geographical perspective has been at the heart of the National Ecosystem Assessment, with Professors Ed Maltby, Roy Haines-Young and others leading work around water components in this assessment (UK National Ecosystem Assessment 2011; Maltby 2012). This work has demonstrated that the ecosystem services approach naturally aligns with a catchment scale.

UK river water quality, measured using traditional chemical and biological indicators, has improved significantly over the past few decades (Defra 2009; 2011; Anderson et al. 2010; Scottish Government 2009). However, diffuse pollutants from multiple-sources that are geographically spread, such as faecal indicator organisms (FIOs), nitrogen and phosphorus from agriculture or pollutants from vehicles in highway runoff, remains a problem for the management of freshwater bodies and rivers (Environment Agency 2007a; National Audit Office 2010). Indeed, FIOs remain the biggest cause of failures in water quality in the UK.

Of rising concern to river water quality and river flow dynamics are a range of emerging pollutants including pharmaceuticals, personal care products, nano-materials, and radio-nuclides (Environment Agency 2000; Hilton et al. 2003). Pollutants caused by the legacy of historical industrial activities such as in mining and manufacturing areas, including the south Welsh valleys, Tees Valley, and Pennines (Hudson-Edwards et al. 1996; Macklin et al. 1997 [5]) are also a problem, particularly where there is no longer an identifiable legal landowner.

At least 50% of UK groundwater used for public supply is showing significant deterioration in quality. The UK water industry has spent hundreds of millions of pounds to address a deteriorating groundwater quality and increasingly stringent drinking water regulatory standards. Groundwater assessments grade just 29% as 'good' or better on the Environment Agency (EA) standard scale[6] (Furse et al. 2006). In Scotland the picture is better, with 64% of all surface water bodies and 76% of ground waters classified as 'good' status or better (Scottish Environment Protection Agency 2009b).

For surface water, the European Union's Water Framework Directive (EU WFD) (European Union 2000) requires incorporation of new 'hydro-geomorphological, chemical and ecological factors' into water quality assessment standards. The EU WFD states that by 2015 member states must be working towards ensuring that all water bodies reach 'good' ecological status, and that they then actually achieve this status by 2027. Heavily modified or artificial watercourses need reach only 'good ecological potential', which can affect a high proportion of urban watercourses and implies a need for a clear definition of what constitutes 'heavy' modification (Rowan 2008).

Considerable evidence from around the world shows that achieving 'good' ecological outcomes in rivers is difficult, one of the main reasons being the necessity to develop new indicators (Harris and Heathwaite 2011). Newer assessment techniques required by the EU WFD are quite different from previous, simpler chemical and biological parameter-based approaches. The EA state that EU WFD monitoring, known as classification, is risk-based and focuses where there is likely to be a problem. It uses a principle of 'one out, all out' which means that the poorest individual result drives overall. These report on over 30 measures, grouped into ecological status (including biology, with new habitat survey techniques, and 'elements' such as phosphorus and pH) and chemical status ('priority substances') (Heathwaite 2010; Page et al. 2012). As a result of the more stringent EU targets evaluations of all English and Welsh water bodies, including rivers and lakes, have shown an indicated fall in quality as a result (Brown et al. 2010). In the UK, regulators and water companies have, wherever possible, worked with farmers to improve land management practices (Glennie et al. 2002). Reconnecting rivers to their floodplains can also deliver water quality improvements, through more rapid removal of pollutants.

[5] Study of the River Swale in the Pennines.
[6] This grades water quality from 'very poor' to 'very good'.

The European Union's Water Framework Directive (EU WFD) emphasises the need for closer ties between river basin management and land use planning, and greater integration between spatial planning systems and the river basin planning system. The EU WFD's success may depend on its emerging relationship with land use planning (White and Howe 2003; Carter 2007; Howes 2008). Policies which help to incentivise land-managers to adopt measures for the water environment are seen as having a role in achieving improved ecological status[7] (Waylen et al. 2011a). Research in the Clyde Valley and the Scottish Highlands (Smith et al. 2011) has concluded there is limited understanding of how this integration might be accomplished, or what it means in practical terms for those involved (particularly planners). For land managers shortages of labour and time are common problems and a lack of social networks can make it harder to learn about new practices or funding schemes, and complexity of rules and regulations means recommendations often appear unworkable or contradictory. The UK River Restoration Centre (part of a major European project RESTORE) has begun this process by focusing on the important role of land use planning in meeting EU WFD targets through river and floodplain restoration (RESTORE 2011).

More than 50 years of agricultural intensification has increased groundwater extraction for irrigation, increased the speed and amount of runoff due to better drainage, and created greater downstream vulnerability to flooding and drought. Preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) are critical components of rural land management, providing benefits from floodwater retention and groundwater recharge (Maltby 2012). By protecting ecologically sensitive areas water quality can be improved, whilst also securing wildlife habitat alongside opportunities for outdoor recreation. Remediation measures to date have included restoration of traditional water and land management systems such as frequent flooding of 'ridge and valley' systems, recreating past water meadow landscapes (Environment Agency 2010; 2012b) and other farming practices (Fiener et al. 2011). Closer to urban areas, Sustainable Urban Drainage Systems (SuDS) also play an important role (Cook and Williamson 1999; Jones and MacDonald 2007; Maltby 2012).

Land management activities over large geographical areas (e.g. spreading manures or mechanical cultivation) may appear to have minimal local impacts, but there can be significant changes to freshwater ecosystems when aggregated as a whole. Similarly, in urban environments, the cumulative impact of seemingly insignificant alterations, such as the paving over of front gardens for parking, can have a tremendous aggregate effect on runoff.

Drainage of peat-dominated catchments and biodiversity has also damaged freshwater ecosystems, with negative effects for both water runoff and quality (Holden et al. 2006). Many peatlands were drained during the 1960s and 1970s for grouse, sheep and timber production, and to provide peat for horticulture and fuel (Holden et al. 2004). An estimated £500 million has been spent over the last decade blocking drains to raise water tables and reverse these changes (Holden et al. 2012) such as the Great Fen project in East Anglia (Maltby and Acreman 2011) and at Lake Vyrnwy in mid-Wales (Wilson et al. 2010). Forestry can have a similarly positive role, with woodland development assisting with improving water quality and sustainable flood management (Forestry Commission 2011; Ellison et al. 2012).

Land use planning in urban areas is also important to water resource managers as changes to the built environment have significant implications for water use and quality (as runoff or as treated wastewater). In the last two decades a green infrastructure movement, linked in particular to landscape architecture and related professions, has promoted innovative, cost-effective and environmentally sustainable approaches to management of water in cities. A variety of technologies are now available which mimic natural processes that slow down, store or reduce storm waters, including rain gardens, porous (permeable) pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for use where water need not be of drinking water quality, such as for flushing toilets (Chappells and Medd 2008). These can be both retrofit, where the average incremental social costs of retrofitting water efficiency measures compare favourably with the costs of traditional resource development schemes (Environment Agency 2007), as well as for new construction. In the east of England alone there were 10,000 new homes were built with water efficiency measures installed as standard between 2006 and 2009 (Waterwise 2010).

[7] The ecological potential of a water body represents the degree to which the quality of the water body's aquatic ecosystem approaches the maximum it could achieve, given the heavily modified and artificial characteristics of the water body that are necessary for the use or for the protection of the wider environment.

Challenge 6

The history of the governance of UK water management is one of incremental developments punctuated by periodic 'revolutions' bringing significant changes. Recent examples of these changes were the privatisation in 1989 of the former regional water authorities and simultaneous creation of the Office of the Water Regulator (OFWAT) and Drinking Water Inspectorate. The establishment of the Environment Agency (EA) followed in 1995 (from the old National Rivers Authority) and the Consumer Council for Water in 2005. Today these agencies regulate the 22 water companies who operate as virtual monopolies within defined geographical regions. The Water for Life White Paper (Defra 2011) ruled out further overhaul of the industry, instead proposing evolutionary changes focused around enhancing competition, improving conservation, and ensuring water companies are more efficient and

Public and stakeholder participation

customer-focused.

One important manifestation of greater customer-focus have been calls for increased public participation in water management decision-making, largely absent to date because key regulatory imperatives behind privatisation were competition, inward investment and economic efficiency. The 1990s periodic price review (through which water company investment programmes and consumer water bills were determined) viewed public engagement solely in terms of the price of water services.

In contrast, the European Union (EU) Water Framework Directive (WFD) (European Union 2000) has driven the move towards increased public involvement. Its mandate for public participation in water management[8] has developed alongside other innovations in water governance to increase accountability in decision-making (Newson 2009). Stakeholder organisations, such as farming, fishing and river trust organisations (Newson 2011) are now prominent on all the River Basin District Liaison Panels in England and Wales. These panels are charged with developing plans for the sustainable management of water resources (mandated by the EU WFD). An initial pilot of a broad stakeholder-based approach to water management at the river basin scale in the north of England suggested some difficulties in achieving broader public engagement, with evidence that the panels offered little scope of real bottom-up decision making (Kaika and Page 2003). Another problem identified has been achieving a truly democratic process where all involved have an equal voice (Oughton and Bracken 2009). New funding from the Department for Environment, Food and Rural Affairs (Defra) for catchment improvements (see Challenge Four) has also taken a stakeholder approach, with bodies like the Westcountry Rivers Trust (WRT) at the forefront of a 'community conservation' approach. This may include 'payments for ecosystem services', the practice of offering incentives to farmers or landowners in exchange for managing their land (see Challenge Five) (River Restoration Centre 2012).

However, despite these developments there are still some who question the need for more 'collaborative' approaches to management as an assumed prerequisite for sustainability and suggest that the 'assumed benefits' of collaborative approaches are not as significant as might be thought (as noted by researchers including Mitchell 2007). In Scotland, where the relationship between spatial planning and river basin planning operates mainly through interactions between the Scottish Environment Protection Agency (SEPA) and local authorities, there is further uncertainty as to how recent reforms to the spatial planning system will interact with the new river basin management plans (RBMPs). Though SEPA painted a fairly optimistic picture, others (particularly local authorities) highlighted their own uncertainty about their specific role in advisory groups (Smith et al. 2011).

[8] This followed the philosophy laid out originally at the 1992 Dublin Conference on Integrated Water Resource Management (IWRM) (World Meteorological Association 1992).

Challenge 7

Water companies in England and Wales take over 16 million cubic metres of water from the environment every day (Environment Agency 2007a) with an average person using about 150 litres per person per day (lpd) (Defra 2008). Household water demand has been increasing since the 1950s. Due to population growth, and changes in the way we use water, more than half of all public water supply is now for domestic use (Defra 2008). In contrast, public water supply usage by industrial, commercial and agricultural sectors has been declining, reflecting in part the changing nature of the UK economy (Defra 2008). Drivers of changing household demand for water services have been many and complex, but social and cultural changes have been especially important, such as changing ideas about comfort, cleanliness and convenience, for example more requent use of washing machines (Shove 2003). Other explanations for increasing total demand include the shift to fewer people living in each household on average, and more intensive water use habits such as increasing use of power showers (Sim et al. 2007).

Future Water, the Government's water strategy for England, outlines a vision for the average person to reduce the water they use by 20 litres per day to 130 litres a day (Defra 2008). Relatively simple measures thought to have a moderate impact on reducing demand have included more water efficient toilets and taps in new developments, installing water efficient washing machines, an increase in the use of dishwashers, the use of cistern displacement devices to moderate the water demand of existing toilets, and more use of grey-water[9] recycling.

Evidence has also shown that simple measures, such as giving consumers more information, can actually make a big difference. For example, during a drought which took place in South East England in 2006, water companies and regulators worked closely together to provide information to customers and this led to significant decreases in domestic water consumption (Chappells and Medd 2008). The challenge for water companies and regulators is how such one-off scarcity-related 'success' stories like this can be translated to a widespread and on-going understanding by individuals of the importance of reducing their water use (Brown et al. 2010). An investigation of water demand as part of the Water cycle management for New Developments (WaND) research consortium concluded that significant changes in user-cultures are likely to be possible only under conditions of great water scarcity or in response to major tariff restructuring, but that this will happen in ways that are not possible to predict (Brown et al. 2010).

Evidence suggests water metering can help to manage domestic water demand.

In recent years the Department for Environment, Food and Rural Affairs (Defra 2008) has argued for a move towards 100% water metering for domestic users, on the grounds that this will drive down water use. Currently only about 35% of UK households are metered for water use, the remainder paying according to the rateable value[10] of their property. Whilst it is acknowledged metered households tend to use approximately 10% less water than non-metered households, it is also true metered households tend to be newer (and therefore more water efficient by design) or inhabited by householders being charged too much under the rateable value tariff (e.g. single occupancy homes) (Brown et al. 2010). Trials in the UK and elsewhere show that while compulsory metering had marked effects on peak demand, with a 30% reduction recorded (Dovey and Rogers 1993) they did not affect average use.

The Folkestone and Dover Water Company (a supply-only business covering a geographically small area in South East England) has to date been the only company to apply to use the existing legislation[11] to impose universal water metering on all customers (Defra 2006). This began in 2007 with Lydd, Kent becoming the first (pilot) town where meters were made compulsory. However, research with householders (Knamiller and Sharp 2009) found that they, rather than understanding the need to reduce water use, felt a sense of victimisation and resentment against the company's (neighbouring) base town of Folkestone where no such measures were being introduced, showing that metering needs to be introduced to local circumstances sensitively. Water loss from supply pipe leakages[12] is another barrier to convincing customers to change their behaviour. Around 1.2 trillion litres is lost in the supply of water to customers each year in England and Wales, though this is down by over a third since its 1994/95 peak (Defra 2010).

[9] Grey-water is waste water generated from domestic activities which can be recycled to use where it need not be of drinking quality (see Challenge Five).
[10] The rateable value is an assessment of the annual rental value of a property made by the Local Authority (last updated in 1973).
[11] Water Industry Regulations Act of 1999.
[12] This includes 'distribution losses' between the treatment works and highway boundary and 'supply pipe losses' from customers'.

Water management objectives link to the UK's air quality and carbon objectives in three ways: 1) energy use, and carbon generated, in the production and distribution of clean water (e.g. drinking water and treating sewage) (Scott and Pasqualetti 2010); 2) water is required for energy generation, especially thermal, nuclear and hydropower; and 3) water acts as a 'sink' and absorbs certain pollutants released into the atmosphere, hence air pollution also causes water pollution.

The water industry is directly responsible for approximately one percent of UK carbon emissions. Water treatment and supply is energy intensive with approximately seven grams of Carbon Dioxide (CO_2) generated for every litre of drinking water produced. Energy use by the water utilities is considered a major issue due to the rising cost of energy required for water treatment and distribution, particularly where pumping is involved (Ainger et al. 2009). Rising water quality standards have resulted in more carbon and higher energy costs for treatment. Ten billion litres of sewage are treated across England and Wales daily using approximately 2,800 GigaWattHours (GWh) of electricity and generating 1.7 million tonnes of greenhouse gas emissions (Staddon 2010). Increasing demands for water could generate significant extra CO_2, particularly because of measures such as desalinisation plants or pumping water over greater distances such as would be seen with a national 'water grid' (see Challenge One).

Water companies are working to reduce their energy use and carbon emissions through a combination of new technologies and demand management. New technologies include artificial wetland systems for carbon-free water treatment and anaerobic biogas production at sites across the country, which generates energy from burning 'waste' gases from the treatment process. There are also financial and carbon savings from designing households so as to re-use grey-water, as not all water needs to be treated to drinking water standards (see Challenge Five). Reducing demand through behavioural change (see Challenge Six) is also being pursued as a means of reducing emissions. As five percent of the UK's total carbon emissions result from heating water there are particular benefits from reduced hot water use, more efficient boilers, better insulated homes, improved temperature control through thermostats (Ainger et al. 2009). Solar energy for heating domestic water can also contribute.

For real progress to reduce energy use from the water sector, new urban developments should consider water efficiency alongside energy efficiency measures in the planning stages. These can include the water quality management and carbon sequestration services potentially available through prudent management of open and green spaces (see Challenge Five) (Chambers 2011).

Electricity generation can also have a negative impact on water resources (Barros et al. 2011). Hydroelectric power plants can have a profound impact on hydro-morphology by altering flow patterns and the movement of sediments (Graf 2006). Also particularly damaging is the creation of significant amounts of methane, a greenhouse gas much more potent than CO_2, through the anaerobic digestion of biomass submerged under reservoirs (Staddon 2010).

Air quality is inextricably linked with water quality in a number of ways. Specific air pollutants can negatively impact on water quality, for example by raising levels of acidity where there is significant sulphur dioxide deposition (Battarbee et al. 2008). Furthermore, climate change caused by excessive air pollution is altering the abilities of water bodies to soak up and act as a 'buffer' for pollutants or to break them down and biodegrade them.

An international perspective and virtual water

UK policy-makers have identified an improved evidence base as a pre-requisite for water managers to better understand and prepare for future pressures and adapt to both longer term trends and locally unpredictable conditions. These pressures should be considered, both in the UK and globally, within the context of the future challenge described by Government Chief Scientist Sir John Beddington as the 'perfect storm' of food, water and energy shortages (which, by 2030, 'has the potential to unleash public unrest and international conflict'). Here, climate change is a key driver of environmental insecurity that is inseparable from the complex interrelationship between food security, energy security and water security (Beddington 2008; 2009). Thus, it is critical to better understand not just the absolute physical shortages of water that may occur as a function of climate change, but also the extent to which existing patterns of water consumption linked to its use in the food and energy sectors contribute to exacerbate these.

On average, each person in the UK uses 150 litres of water per day. Yet if you also consider the water that is utilised elsewhere in the world to make the products and provide services for the UK, with associated impacts in terms of carbon produced, and air and water pollution, there is a further environmental impact to be considered, with the total water 'footprint' of each person actually being much higher. This is known as the concept of 'embedded' or 'virtual' water, a term developed by the work of geographer Professor Tony Allan, and for which he received the Stockholm Water Prize in 2008. Water used during the production cycle may not exist at the point of consumption, but is embedded as part of the product chain (Allan 2011). Seventy percent of total global water use is for agricultural production, though only a small fraction of that water is physically locked up in the product that is ultimately consumed (Berrittella et al. 2007). Therefore in consuming foodstuffs, we inadvertently place a demand on the water-based resources at the site of production. Almost 90% of a human being's water needs are accrued through food production (Lui and Savenije 2008), but this same analysis also applies to the clothes people wear, cars driven, and in fact every element of the goods and services that support someone's consumption and way of life.

Building on this work, a water footprint handbook has been developed by the Water Footprint Network to show how these can be calculated for individual processes and products, nations and businesses. For example, a standard (125ml) cup of coffee actually uses about 140 litres of water by far the largest part for growing the coffee plant (within developing world countries), but large amounts also accrue in its processing and transport (Hoekstra et al. 2009). Similarly one 150 gram beefburger has as much as 2400 litres of 'embedded' water (Lang 2008).

In theory, countries experiencing water stress can alleviate local water shortages by importing water intensive products and countries that have a water surplus can benefit financially by exporting water intensive commodities like food, cotton and paper (Hoekstra 2003). However, a more common scenario is that water scarce countries, such as in northern Africa and the Middle East, produce and export water intensive goods (Swain 2004). An unintended, but potentially dangerous consequence of the globalisation of food production has been to alleviate water insecurity in Europe, whilst increasing it in certain citrus and winter vegetable producing countries such as Kenya and India. Although the EU is regarded as a region of relative water security, it is therefore dependent to some extent on there being increasing levels of water insecurity in other parts of the world (Hoekstra and Chapagain 2007).

Looking ahead over the next 20 years and beyond, the UK will face challenges in the continued provision of water services for a population that is growing and ageing, where fewer people are living in each household on average, and where this population becomes increasingly concentrated in the (already water stressed) Greater London area and South East of England. Changes in lifestyle and individual behaviour may also become more water-intensive and add to these pressures.

It will also be necessary to take account of the impact of other physical factors on groundwater and demand for water, including changing land use, particularly the effects of increased urbanisation (in part linked to a growing population). In addition, increased climate variability and extreme weather events present a great challenge to the water sector. The most recent climate projections (UKCIP09) (Jenkins et al. 2009) suggest that even under 'medium emissions' scenarios the UK could experience significant changes in the timing of precipitation, with drier summers and higher rainfall in winter and that volatility will become more common. For example, there may be an increasing need for irrigation in summer to maintain agricultural production levels.

The drought experienced in England in 2011-12, particularly focused in the South East, arose from low autumn and winter rainfall continuing into a dry spring. The geography of where rain actually falls may change too, with existing northwest / southeast differences deepening further (Foresight Land Use Futures Project 2010; Environment Agency 2009). Recent regional climate change modelling by the UK-based Hadley Centre shows that the likelihood of intense rainfall events, such as the historic flooding in England in June and July 2007, is also increasing (Staddon 2010).

Broader environmental systems are undergoing a period of unprecedented change. Whereas much attention has focused on climate and marine systems, there is growing evidence of changes to freshwater systems (Whitehead et al. 2009). Changes in weathering rates over the past 50 years as a result of changes in climate and land use are changing the chemistry of rivers (Raymond and Cole 2003). A recent IPCC Report (IPCC 2008) concludes that the effects of climate change are challenging a 'traditional assumption that past hydrological experience provides a good guide to future conditions'. Consequently this includes a need for new models of relevant environmental variables to predict the consequences of climate change on water availability (Heathwaite 2010). Critically for freshwater ecosystems, hydrological connectivity, and therefore diffuse pollution risk, may change under a changing climate (Heathwaite 2010) (see Challenge Four).

As the UK Government Office of Science Foresight initiatives have highlighted, it may be difficult to plan for both floods and droughts simultaneously (Foresight Land Use Futures Project 2010). Immediately prior to the floods experienced across England and Wales in June and July 2007, water managers in England and Wales were considering how to manage dwindling water supplies had the pre-existing drought continued (2003-2006 was a very dry period). Furthermore, the wider introduction of Sustainable Urban Drainage Systems (SuDS) (see Challenge Five) reflects lessons learnt (Environment Agency 2008) from the 2007 floods but not in a way that considers how SuDS could also be used to provide water supply benefits in the (inevitable) event of drought. There may be a need for the construction of new and different sorts of water infrastructure (see Challenge One) and natural flood management initiatives are advocating more storage throughout catchments including the upper reaches, floodplains, as well as SuDS in urban areas.

Climate adaptation measures linked to forecast changes in water availability have tended to focus on the supply side of the water balance, but increasingly demand recognition is being recognised as being significant. Popular measures include water metering and attempts to influence water consumption patterns and social behaviour (see Challenge Seven). To deliver sustainable solutions that address the multiple stressors on water availability (see Challenge Two) and protect ecosystem services (see Challenge Three) means a coordinated assessment of changes in land use (see Challenge Five) linked to water availability and supply challenges at a range of geographical scales, from catchment to regional, with changes in terrestrial and freshwater biogeochemical processes (see Challenge Four).

The REFRESH programme (Adaptive Strategies to Mitigate the Impacts of Climate Change on Freshwater Ecosystems) is one such project beginning this work, with research examining the future challenges (environmental, social and policy) facing implementation of the European Union (EU) Water Framework Directive (WFD) and associated commitments related to the EU Directive on the conservation of natural habitats and of wild fauna and flora (European Union 1992). These latter commitments have included the development of an ecological network of special protected areas known as 'Natura 2000' covering around 18% of the land area in the EU. Research indicates that so far policies are not likely to be sufficiently 'future-proofed' but that some responses, including promoting partnership working (see Challenge Six) may help to sustainably protect freshwaters and safeguard ecosystem services (Waylen et al. 2011b).

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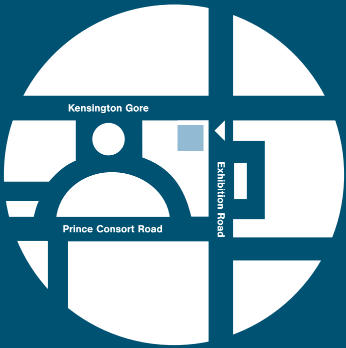

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