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PART I

INTRODUCTION TO WATER SUPPLY

Chapter 1

The water business

1.1 Introduction

The water supply industry is vitally important not only to maintain the health of the community, but for the sustainability of industry, business and agriculture. Without adequate water supplies our present society would never have evolved, and our lives today would be unrecognizable. Our dependence on treated water is now incalculable, and threats to that supply are comparable to the worst natural and man-made disasters. The volumes of water consumed each day by agriculture, industry and the public are vast, requiring an enormous infrastructure to satisfy the demand. Like the other service providers, electricity, telephone and gas, the water utilities deliver their product to the home, which requires a network of distribution pipes to service each household, but unlike the other utilities these are stand alone local or regional networks, rather than integrated national supply networks.

In England and Wales there are 26 private water companies that together supplied 52.7 million consumers in 2004/5 with 15 807 million litres (Ml d^{-1}) of water each day. Sixty-eight per cent of this came from surface waters and the remainder (32%) from groundwater. It requires 1344 plants to treat this volume of water, which is supplied to consumers via 326 471 km of distribution mains. When this is broken down by region, the greatest demand is in the south-east and north-west regions, which have the largest populations. However, the areas of highest demand do not normally correspond to the areas where adequate water resources are to be found, so shortages occur. The current demand for potable water in England and Wales has stabilized and is currently at 91% of the peak demand recorded in 1990/1 (Table 1.1).

1.2 Water consumption

Water demand varies significantly between countries due to differences in culture, climate and economic wealth (Smith and Ali, 2006). The demand for water also varies over the 24-hour period. This is known as the diurnal variation, with peak usage in the UK occurring between 07.00 and 12.00 and from

Table 1.1 *Water supplied to the public distribution system 1990/1–2004/5. Adapted from Defra (2006) with permission from Defra*

		Ml d ⁻¹														
		1990/1	1991/2	1992/3	1993/4	1994/5	1995/6	1996/7	1997/8	1998/9	1999/2000	2000/1	2001/2	2002/3	2003/4	2004/5
United Kingdom																
England and Wales ¹																
metered ²		4824	4785	4646	4572	4687	4676	4743	4791	4866	5076	5142	5464	5509	5704	5765
unmetered ³		12558	12414	12109	12185	12424	12643	11918	11192	10477	10254	10117	10319	10312	10373	10042
England and Wales total		17382	17199	16755	16757	17111	17319	16661	15983	15343	15331	15259	15783	15821	16077	15807
Scotland																
metered ²		656	643	603	610	612	574	625	555	553	531	438	532	454	478	470
unmetered ³		1645	1596	1603	1662	1651	1748	1686	1782	1775	1832	1962	1876	1933	1919	1920
Scotland total		2301	2239	2206	2272	2263	2322	2312	2336	2329	2363	2400	2408	2387	2397	2390
Northern Ireland																
metered ²		143	152	186	184	188	186	187	174	158	157	147	144	156	151	148
unmetered ³		538	527	483	486	498	517	520	516	534	547	573	591	558	525	492
Northern Ireland total		681	679	669	670	686	703	707	690	692	704	720	735	714	676	640
United Kingdom ¹																
metered ²		5623	5580	5435	5366	5487	5436	5555	5520	5577	5764	5727	6140	6119	6333	6383
unmetered ³		14741	14537	14195	14333	14573	14908	14124	13490	12786	12633	12652	12786	12803	12817	12454
United Kingdom total		20364	20117	19630	19699	20060	20344	19680	19009	18364	18398	18379	18926	18922	19150	18837

¹ Includes water supplied by water supply companies.

² Metered water is water measured at the point of delivery to premises.

³ Unmetered water includes leakage from the distribution system and water used for miscellaneous purposes such as fire-fighting, sewer cleaning, water mains flushing and temporary supplies for construction sites.

Table 1.2 *Typical current domestic water use in England and Wales*

Use	%	Use	%
Toilet	35	Washbasin	8
Kitchen sink	15	Outside use	6
Bath	15	Shower	5
Washing-machine	12	Dishwasher	4

Table 1.3 *Average water use of a range of activities and appliances*

Purpose of water use	Frequency	Litres
Cooking, drinking, washing-up and personal hygiene	per person per day	27
Bath	one	90
Shower	one	20
Toilet	one	6–9 ^a
Automatic washing-machine	one	100
Dishwashing machine	one	50
Hosepipe/sprinkler	per minute	18

^a Modern cisterns now use 4 litres, or more commonly 6 litres, compared to 9 litres in older systems.

18.00–20.00 each day (Figure 20.1). Demand is greater during weekends by about 12%, with demand being higher in the summer than in the winter. In the UK the typical household water consumption, typical here meaning a family of two adults and two children, is currently 5101 d⁻¹. This is equivalent to a per capita water consumption rate of 150–180 l d⁻¹. Less than 20% of the water supplied is consumed for drinking or food preparation, with toilet flushing the single major use of water (Table 1.2). Ownership of certain white goods, which has increased dramatically over the past 20 years, has an important influence on water usage. For example in the UK, 94% of households owned a washing-machine in 2003 compared to just 79% in 1983. A similar trend has been seen with dishwasher ownership, which is currently 31% in the UK compared to 5% over the same period. On average a dishwasher adds an extra 6 l d⁻¹ to the per capita consumption, increasing the overall demand by about 4%. Table 1.3 gives some idea of the amount of water such appliances use. At the top of the list are automatic washing-machines, which can use a staggering 100 litres each time they are used. A bath uses on average 90 litres a time compared with a shower that can use as little as 5 l min⁻¹, although this depends on the showerhead used. For example, a power shower can use in excess of 17 litres per minute. Garden sprinklers use about a 1000 l h⁻¹, which is the average daily water usage for seven or eight people. Clearly not all the public supplies are utilized for

Table 1.4 *Estimated daily use of water supplied by the former Severn and Trent Water Authority during 1984–5. Adapted from Archibald (1986) with permission from the Economic and Social Research Council*

Type of use	Amount used (MI d ⁻¹)	Purpose	Amount used (MI d ⁻¹)
Domestic	840	Basic	288
		Toilet flushing	242
		Bathing	155
		Washing-machine	114
		External use	27
		Luxury appliances	14
Industrial and commercial	530	Processing	256
		Domestic	153
		Cooling: direct	77
		Cooling: recycled	44
Agricultural	50	Livestock	35
		Domestic	10
		Protected crops	3
		Outdoor irrigation	2
Unaccounted for	522	Distribution system	287
		Consumers' service pipes	167
		Trunk mains	52
		Service reservoirs	16
Total	1942		

domestic purposes. This is illustrated by the analysis of daily water usage in 1984–5 by the former Severn and Trent Water Authority. Of the total 1942 MI d⁻¹ supplied each day, 840 MI was used for domestic purposes, 530 MI for industrial, 50 MI for agricultural purposes and a remarkable 522 MI (26.9%) was lost every day through a leaky distribution system (Table 1.4).

Losses from leaks are a widespread problem as water mains not only deteriorate with age, but are often damaged by heavy vehicles, building work or subsidence. Leakage control is a vital method of conserving water. Detecting and repairing leaks is both labour intensive and time consuming, which means that it is very expensive. However, if leaks are not controlled then water demand will escalate, with most of the extra demand seeping away into the ground instead of making its way to the consumer. In England and Wales 3608 MI of the 15 378 MI of treated water supplied each day was lost during 2004/5 through leakage, 2584 MI d⁻¹ from the distribution mains (17% of total input) and 1024 MI d⁻¹ from supply pipes (7% of total input). The current leakage rate is

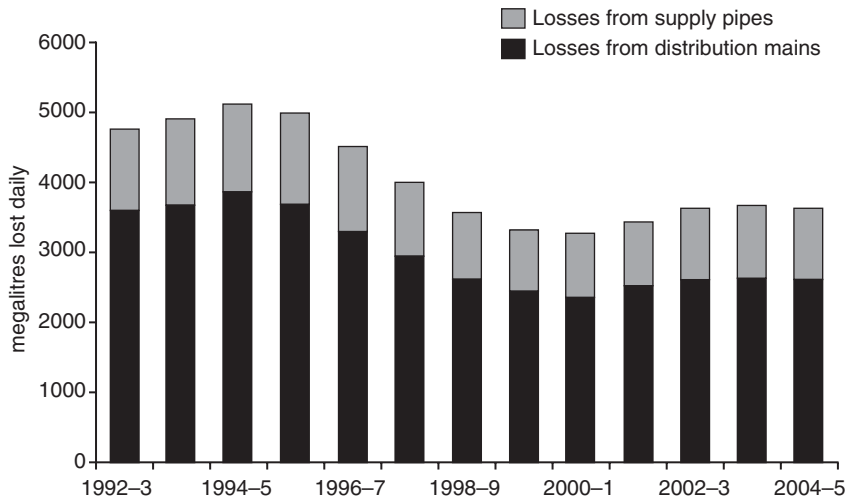


Figure 1.1 Water leakage reported in England and Wales during the period 1992/3 to 2004/5. Adapted from Defra (2006) with permission from Defra.

33% lower than the peak leakage rates reported in 1994/5, but has remained static each year since 1997/8 at between 22% and 25% despite a huge investment by the water companies in repairs and replacement to the distribution network each year (Figure 1.1). Currently, 24% of all water treated is being lost due to leakage.

Studies of water usage are very difficult to carry out, as individual use of water is so variable. Actual average consumption values may also hide water lost by leakage within the household plumbing system for example. The National Water Council (1982) carried out a detailed study of water usage and found that the actual average consumption levels were slightly lower than those calculated by the companies at that time (Table 1.5). This and subsequent studies on the pattern of domestic water usage have shown that per capita consumption decreases slightly with an increase in household size, and that social groupings also have an influence, with Social Group A using about 501 d^{-1} more than Social Group E (Bailey *et al.*, 1986) (Table 1.5). It was also shown that the daily volume of water consumed per household for non-potable purposes is dependent on the size of the household. So on a national basis about 3% of the total volume of domestic water consumed each day is used for potable purposes, which is equivalent to about 10 litres for the average household. Interestingly, 25% of the first draws of water taken from the system each day are for potable purposes, a habit that may have significant consequences in those areas where the water is corrosive and lead or galvanized plumbing is used (Chapter 27).

1.3 Acceptable water quality

Water rapidly absorbs both natural and man-made substances, generally making the water unsuitable for drinking without some form of treatment.

Table 1.5 *Comparison of average water consumption per person in three water company areas with respect to household size and socio-economic group*
 Adapted from National Water Council (1982) with permission from the National Water Council

	Average water consumption (1 d ⁻¹)		
	South West	Severn Trent	Thames
Household size			
1	126	116	136
2	124	118	151
3	118	109	123
4	110	92	116
5	103	96	103
6	97	75	97
7+	92	69	64
Social group			
A	138	126	134
B	124	117	126
C1	122	100	124
C2	111	93	113
D	103	93	102
E	86	76	94

Important categories of substances that can be considered undesirable in excess are:

1. *Colour*. This is due to the presence of dissolved organic matter from peaty soils, or the mineral salts of iron and manganese.
2. *Suspended matter*. This is fine mineral and plant material that is unable to settle out of solution under the prevailing conditions.
3. *Turbidity*. This is a measure of the clarity, or transparency, of the water. Cloudiness can be caused by numerous factors such as fine mineral particles in suspension, high bacteria concentrations, or even fine bubbles due to over-aeration of the water.
4. *Pathogens*. These can be viruses, bacteria, protozoa or other types of pathogenic organism that can adversely affect the health of the consumer. They can arise from animal or human wastes contaminating the water resource.
5. *Hardness*. Excessive and extremely low hardness are equally undesirable. Excessive hardness arises mainly from groundwater resources whereas very soft waters are characteristic of some upland catchments.
6. *Taste and odour*. Unpleasant tastes and odours are due to a variety of reasons such as contamination by wastewaters, excessive concentration of certain chemicals such as iron, manganese or aluminium, decaying vegetation, stagnant conditions due to a lack of oxygen in the water, or the presence of certain algae.

7. *Harmful chemicals*. There is a wide range of toxic and harmful organic and inorganic compounds that can occur in water resources. These are absorbed from the soil or occur due to contamination from sewage or industrial wastewaters.

Water treatment and distribution is the process by which water is taken from water resources, made suitable for use and then transported to the consumer. This is the first half of the human or urban water cycle, before water is actually used by the consumer (Figure 1.2). The second half of the cycle is the collection, treatment and disposal of used water (sewage) (Gray, 2004).

The objective of water treatment is to produce an adequate and continuous supply of water that is chemically, bacteriologically and aesthetically pleasing. More specifically, water treatment must produce water that is:

1. *Palatable* – that is, has no unpleasant taste;
2. *Safe* – it should not contain any pathogenic organism or chemical that could be harmful to the consumer;
3. *Clear* – be free from suspended matter and turbidity;
4. *Colourless and odourless* – be aesthetic to drink;
5. *Reasonably soft* – to allow consumers to wash clothes, dishes and themselves without excessive use of detergents or soaps;
6. *Non-corrosive* – water should not be corrosive to pipework or encourage leaching of metals from pipes or tanks;
7. *Low in organic content* – a high organic content will encourage unwanted biological growth in pipes or storage tanks, which can affect the quality of the water supplied.

With the publication of drinking water standards such as the European Union Drinking Water Directive (98/83/EEC) (Appendix 1) and the Safe Drinking Water Act (1974) in the USA, which has given rise to the National Primary and Secondary Drinking Water Standards (Appendix 2), water must conform to the standards laid down for a large number of diverse parameters. In England and Wales, for example, the European Directive is enforced by the Water Supply

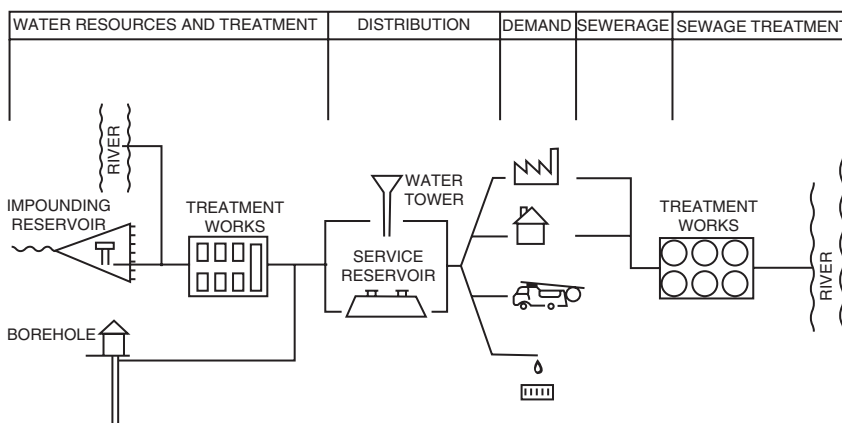


Figure 1.2 Schematic diagram showing the role of the water companies in supplying water to the consumer and subsequently treating it before returning it to the hydrological cycle (Latham, 1990). Demands shown are industrial, domestic, fire-fighting and leakage. Adapted with permission from the Chartered Institution of Water and Environmental Management.

(Water Quality) Regulations (2000), which requires the water supply companies to deliver water to consumers that is wholesome and defines clearly what this term means. Consumers expect clear, wholesome water from their taps 24 hours a day, every day. Although water that is unaesthetic, for example due to colour or turbidity, may be perfectly safe to drink, the consumer will regard it as unpalatable and probably dangerous to health. Problems not only originate from the resources themselves, but during treatment, distribution and within the consumer's home (Chapter 3).

1.4 Water utilities

Water supply has traditionally been a function carried out by state or regional authorities, but throughout Europe, Canada, Australia and the USA this role is increasingly being transferred to the private sector. Regulation and the overall quality control of drinking water remains largely with Governments and their agencies; however, the day-to-day operation is now largely privatized. There is growing concern that there may be a slow globalization of the market with a relatively small number of large companies dominating this vital product; also there is little evidence to support the idea that private companies are any more or less efficient than the public sector in supplying water (Hall and Lobina, 2005). Clearly, it is extremely difficult to generalize, so an example of how drinking water is managed and regulated in a single country, the UK, is given below.

1.4.1 Water undertakers and regulation in the UK

Prior to 1989 a mixture of private companies and public-owned water authorities provided drinking water in England and Wales. Since September of that year all water services have been provided by the private sector. Ten Water Service Companies created by the privatization of the 10 water authorities deliver both water and sewerage services, while 29 water supply companies that had always been in the private sector supplied water only. The number of water supply companies has subsequently been reduced to 16 through a number of amalgamations (Table 1.6).

The situation elsewhere in the British Isles is rather different. In Scotland the three public water authorities, North of Scotland Water, East of Scotland Water and West of Scotland Water were amalgamated to form a single new authority, Scottish Water in April 2002 (www.scottishwater.co.uk). Although answerable to the Scottish Executive it is structured and managed as a private company. Northern Ireland is the only part of the UK where water supply and sewerage provision remains within the public sector. The Water Service is an Executive Agency that was set up after local government reorganization in 1996 within the Department for Regional Development (www.waterni.gov.uk); it became a Government Company in April 2007.

Table 1.6 *List of the 10 water and sewerage companies and 16 water only companies supplying drinking water in England and Wales and their web addresses*

Water and sewerage companies

Anglian Water Services Ltd	www.anglianwater.co.uk
Dwr Cymru Cyfyngedig (Welsh Water)	www.dwrcymru.co.uk
Northumbrian Water Ltd	www.nwl.co.uk
Severn Trent Water Ltd	www.stwater.co.uk
South West Water Ltd	www.southwestwater.co.uk
Southern Water Services Ltd	www.southernwater.co.uk
Thames Water Utilities Ltd	www.thameswater.co.uk
United Utilities Water Plc	www.unitedutilities.com
Wessex Water Services Ltd	www.wessexwater.co.uk
Yorkshire Water Services Ltd	www.yorkshirewater.com

Water only companies

Albion Water Ltd	www.albionwater.co.uk
Bournemouth & West Hampshire Water Plc	www.bwhwater.co.uk
Bristol Water Plc	www.bristolwater.co.uk
Cambridge Water Company Plc	www.cambridge-water.co.uk
Cholderton and District Water Company Ltd	www.water-guide.org.uk/cholderton-water.html
Dee Valley Water Plc	www.deevalleygroup.com/DVW/DVW.htm
Essex & Suffolk Water (Now part of Northumbria Water Ltd)	www.eswater.co.uk
Folkestone & Dover Water Services Ltd	www.fdws.co.uk
Hartlepool Water Plc (Now part of Anglian Water Services Ltd)	www.hartlepoolwater.co.uk
Mid Kent Water Plc	www.midkentwater.co.uk
Portsmouth Water Plc	www.portsmouthwater.co.uk
South East Water Plc	www.southeastwater.co.uk
South Staffordshire Water Plc	www.south-staffs-water.co.uk
Sutton and East Surrey Water Plc	www.waterplc.com
Tendring Hundred Water Services Ltd	www.thws.co.uk
Three Valleys Water Plc	www.3valleys.co.uk
