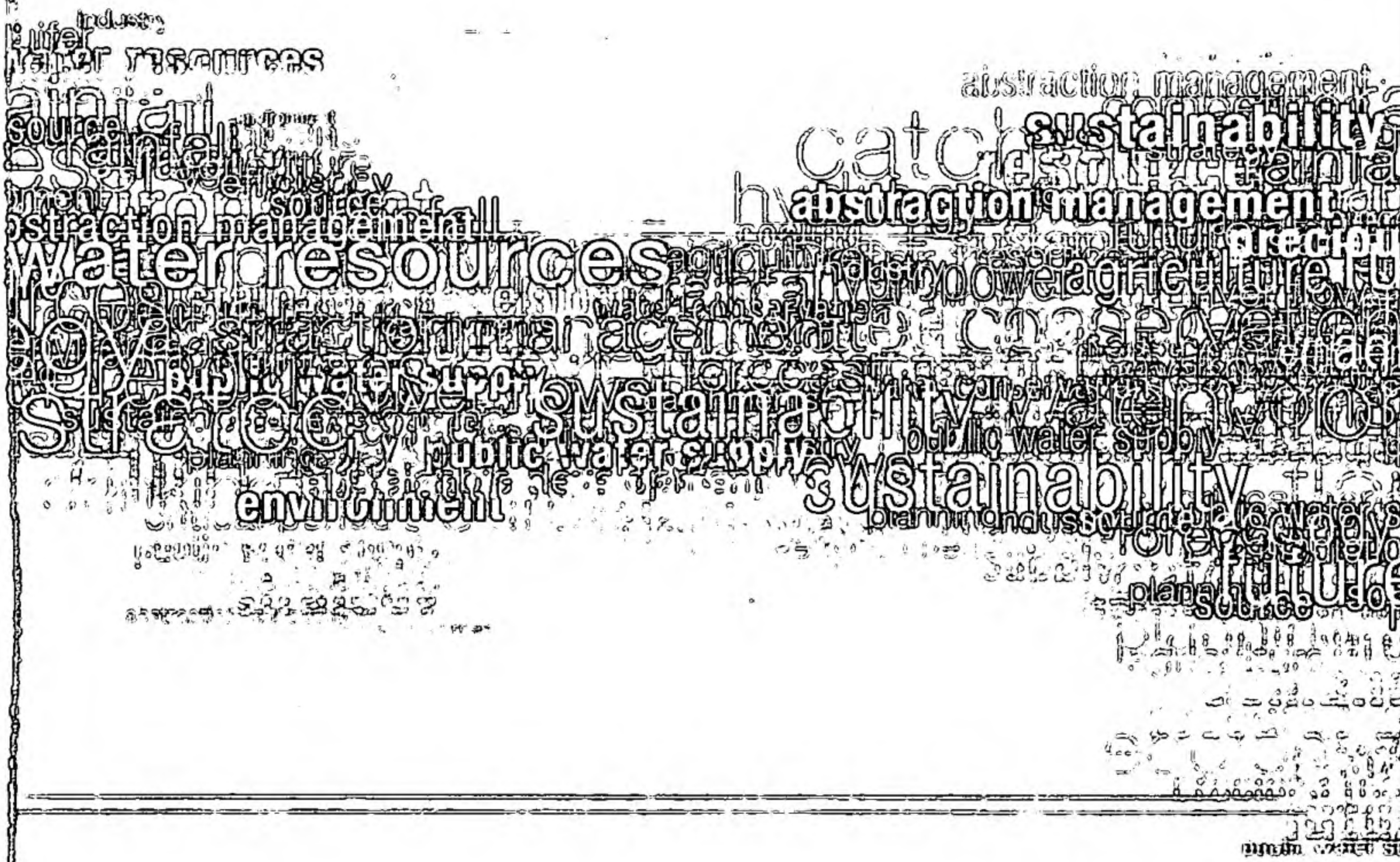
EA-WATER RESOURCES BOX 10



A scenario approach to water demand forecasting

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ENVIRONMENT AGENCY

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Contents

List of figures

List of tables

Summary

Introduction

This report provides the detailed background on the methods and assumptions we used to derive the forecasts of demand that underpin the national strategy and its supporting strategies covering the eight Agency regions of England and Wales.

The Environment Agency is the statutory body with a duty to secure the proper use of water resources in England and Wales. In accordance with this duty we have prepared a water resources strategy which looks some 25 years ahead. The strategy considers the needs for water, both of the environment and of society, and examines the uncertainties about future water availability and demand.

Forecasting approach

Many of the factors affecting the use and management of water resources are influenced by changes in social values and systems of governance. To understand the implications of such changes we have applied a scenario-based approach to water demand. Scenarios are illustrations of possible future conditions. Drawing on the Department of Trade and Industry's Foresight "Environmental Futures" framework, we have developed water demand scenarios that address the different ways in which society may use and value water in the future.

Our use of scenarios marks an important step forward. By drawing on the "Environmental Futures" framework we can consider four possible future societies. Each scenario sets out a broad indication of the social, economic, political and technological changes that will lead to changes in the way the environment is valued and used. These socio-economic scenarios are not predictions of some future society, nor a set of prescriptions of how the future will evolve. They allow us to track the effects of different combinations of social values and systems of governance on the use and management of water. By understanding the factors driving demand under each scenario, we can develop an approach that involves managing water use and expectations to produce a strategy that is robust and flexible.

In applying a scenario-based approach to water demand we have demonstrated the importance of component and micro-component based forecasts. Only by considering the sensitivity of each micro-component to the different drivers of demand have we been able to link water demand to the Foresight "Environmental Futures" framework. We have assumed that the drivers of demand remain constant across all four scenarios. This means that we have been able to develop a single forecasting model for each component of demand, to which we apply scenario-specific assumptions. Such an approach enables us to illustrate and quantify the impact of different combinations of social values and systems of governance on future water use. The components we have used are:

- household;
- leakage;
- non-household;

} for public water supply

- primary industry and manufacturing;
- spray irrigation.

} for direct abstraction

For each component we have looked at the drivers of demand and considered how each will vary under the four scenarios. The starting point for each scenario is the same. The technologies and policies included within the four scenarios are all available within the UK or overseas today. The assumptions are therefore within the present bounds of possibility and represent a realistic assessment of likely change.

Where next?

The Environment Agency's water resources strategy takes the output from the demand forecasts and proposes a series of actions. By illustrating how the various components of demand might change, the actions necessary for their management become more evident. For example, the significant rise in leakage under one scenario illustrates the importance of continued attention to leakage control. Similarly, active promotion of water efficiency will be essential if we are to achieve our vision of sustainable water resources development.

An annual bulletin will report on progress against this strategy. We also plan to review it completely in a few years, acknowledging that unforeseen social, economic and political changes can have unexpected consequences for the way in which water is used and managed.

We aim to improve continually the basis on which our forecasts are developed. To do this, the component forecasts will be kept under review to reflect new information and research as it becomes available. In a number of key areas further collaboration is needed between the Agency and the water, agricultural and manufacturing industries. We shall work to facilitate co-operation across sectors and between different organisations.

1 Introduction

Water is essential for natural life and for human use. We use it in our homes and gardens, in industry and commerce, and in agriculture. The way we use water has a direct impact on the natural environment. This means it is essential to have a secure framework for the management of water that protects the long-term future of the water environment while encouraging sustainable development.

The Environment Agency is the statutory body with a duty to secure the proper use of water resources in England and Wales. In accordance with this duty, we have prepared a national water resources strategy. This sets out the principles and a broad overview of the actions that we consider necessary to manage water resources over the next 25 years. We have also developed water resources strategies for our seven regions of England and for Wales. These add local detail and provide further information that will help those involved in all aspects of water resources management to plan their activities.

This technical report is intended to support these documents, providing greater detail on the methods and assumptions employed in the derivation of our scenario-based forecasts. The report will be of particular interest to those with a broad understanding of water demand forecasting techniques, as well as those involved in the development and use of socio-economic scenarios. The objective of the report is to set out in a transparent way the forecasting framework, methods and assumptions used in the development of our water demand scenarios.

1.1 Water resources for the future: the water resources strategy

The strategy, which looks some 25 years ahead, considers the needs for water both of the environment and of society. The Agency's vision for water resources for the next 25 years is:

Abstraction of water that is environmentally and economically sustainable, providing the right amount of water for people, agriculture, commerce and industry, and an improved water-related environment.

The strategy has 10 objectives:

- to illustrate the impact of different social and economic choices on future water use;
- to manage water resources in a way that causes no long-term degradation of the environment;
- to improve the state of existing degraded catchments;
- to ensure that water is available to those who need it, and that it is wisely used by all;
- to indicate the present state of water resources;
- to cater robustly for risks and uncertainties;
- to promote the value of water to society and the environment;
- to review feasible water management options including innovative solutions where appropriate;
- to provide a framework for logical decisions to be taken at the right time;
- to identify actions and opportunities for the Agency and others to work together to achieve our vision.

The strategy contributes to various themes of the Agency's new *Environmental Vision* (Environment Agency, 2000), including:

- a better quality of life;
- an enhanced environment for wildlife;
- a greener business world;
- wiser, sustainable use of natural resources;
- improved and protected inland and coastal waters;
- limiting and adapting to climate change.

The long-term approach that we have taken complements the *Vision*, showing how the thematic approach to improving our environment translates into tangible actions affecting a specific sector. In water resources, actions in one place have implications elsewhere, making the direct consideration of links especially appropriate.

In preparing the national and regional water resources strategies we have looked at the present resource situation, identifying areas where abstraction needs to be reduced to correct damage and to improve the environment. As part of this work we have also developed new, scenario-based forecasts. These assess future demands for water for public water supply, agriculture and industry. The national and regional water resources strategies describe much of the detail related to the results of these forecasts.

1.2

A scenario-based approach to forecasting water demand

Many of the factors affecting the use and management of water resources are influenced by changes in social values and systems of governance. To understand the implications of such changes we have applied a scenario-based approach to water demand. Scenarios are illustrations of possible future conditions. Drawing on the Foresight "Environmental Futures" framework (DTI, 1999), we have developed water demand scenarios which address the different ways that society may use and value water in the future.

Traditionally, scenarios are used by forecasters as standard tools to assess sensitivity to changes in key components. This approach was adopted by the National Rivers Authority (NRA) in its forecasts included in the 1994 water resources strategy *Water: Nature's Precious Resource*. Today, we are using scenarios to help us think about how social values and systems of governance might change in the future. They are not a set of prescriptions of how the future will evolve. By tracking the impact of different combinations of societal and governmental action on the use and management of water we can see the possible choices and options that society might face in the future. By understanding the factors driving demand, it is easier to identify the type and scale of water resource management measure(s) that might be required. Hence we are able to specify more clearly the combination of resource management, demand management and resource development measures that may be appropriate. Although scenarios are not new within the context of water demand forecasting, the way in which we have developed and used them within our water resource strategies represents an important development. The demand scenario approach marks a clear departure from the old "predict and provide" doctrine, which assumed that all possible future demands should be met through the development of additional resources.

In applying a scenario-based approach, we recognise that changes in social values, regulations and policies will have a variable impact on the different components of water demand. Given the different drivers of demand it is conceivable that within the same scenario some components will increase while others decrease.

To track such changes and illustrate their impact we have broken down total water demand into the components of public water supply and direct abstraction use, in line with the UKWIR/NRA (1995) *Demand Forecasting Methodology*.

We have developed water demand scenarios for the following components of public water supply:

- household;
- leakage;
- non-household.

For direct abstraction, we have developed water demand scenarios related to:

- agricultural spray irrigation;
- primary industry and manufacturing.

In developing the water demand scenarios, three objectives have been set:

- to develop a nationally consistent set of component forecasts;
- to use best available information to develop consistent data sets and forecast assumptions;
- to apply forecast methodologies in line with water industry "best practice".

1.3

Links with other water planning initiatives

Our water resources strategies are part of a framework of integrated water resources planning carried out both by the Agency and by water companies. These cover different timescales and different geographical areas.

The strategies look 10 to 25 years ahead, and are for the whole of England and Wales. They cover all aspects of water resources management, including public water supply. This is always prominent in national and regional strategies, because it is such an important part of water use. Each water company has its own water resources plan, setting out its view of how it will manage water resources over the next 25 years. These plans complement the supply-demand balance submissions that water companies make to the Office of Water Services (Ofwat), the economic regulator of water companies, every five years. Annual updates to water company plans are submitted to the Agency for review. The plans detail the actions that water companies intend to take, and are an important part of the water resources planning process. In developing our scenario-based forecasts for the components of public water supply we have drawn, in the first instance, on information from the water companies' water resources plans. However, the sources of population and household data varied between companies and so, in order to ensure a single data set consistent with official national projections, we used a separate source for this information.

The purpose of our strategies is to set the bounds within which decisions will be reasonable. This means that we must develop a good understanding of the values of society and Government, and combine these with a rigorous assessment of future demands and pressures to provide a framework for decision-making. In some cases, these values will mean that there is an obvious course of action. In others, limited time will mean that a single course of action will have to be chosen and acted upon. Our approach must be sufficiently robust to deal with all sorts of uncertainty and still meet the objectives that we have identified for our strategies. In providing strategies, it is not our intention to constrain the commercial decisions of water companies and other abstractors, but to provide a way forward that ensures that decisions meet the wider objectives of society as a whole, as well as any statutory obligations. The strategy sets a broad framework within which detailed plans for action by water companies and other abstractors can be drawn up.

1.4

Structure of the report

In this report we set out the forecasting framework, methods and assumptions which we have applied in developing component-based water demand scenarios. The report is divided into eight chapters. Chapter 2 is a summary of previous approaches to water demand forecasting, identifying the key drivers of demand related to each component. This provides the framework on which we developed our component-based demand scenarios. Chapter 3 explains the Foresight "Environmental Futures" framework approach, and the principles underpinning our application of this framework to the components of water demand. Chapters 4 to 7 relate to each component of demand (household, leakage, industry and commerce and spray irrigation respectively), and set out the methods, data sources and assumptions we have developed to produce water demand scenarios. The impact of each scenario on total water demand is discussed in Chapter 8. In the final chapter we draw our conclusions and identify areas requiring further work.

This report will be the basis for ongoing dialogue with stakeholders. We will keep the scenario-based forecasts under review and adapt them as new information becomes available and new approaches are developed. We welcome views on the material presented here, on our use and development of these scenario-based forecasts. If you wish to comment, please write to the Head of the National Water Demand Management Centre at our Worthing address.

2 Forecasting framework

In this chapter we set out the framework that underpins the development of the water demand scenarios. Assessment of the drivers of component demand forms the corner-stone of our approach. It provides the basis for linking the Foresight "Environmental Futures" framework to the components of water demand. The details of this approach are discussed in subsequent chapters.

Here we assess the drivers of component demand and their relative sensitivity to socio-economic change. Section 2.1 reviews historic forecasts against actual demand. As well as assessing the role of improved forecast methods and data sets, the analysis demonstrates the effects of unforeseen social, economic and political changes on actual water demand. Section 2.2 considers the forecasts developed by water companies in their recently submitted water resources plans. Section 2.3 describes how we link high-level socio-economic changes to water demand through analysis of the key drivers of component demand.

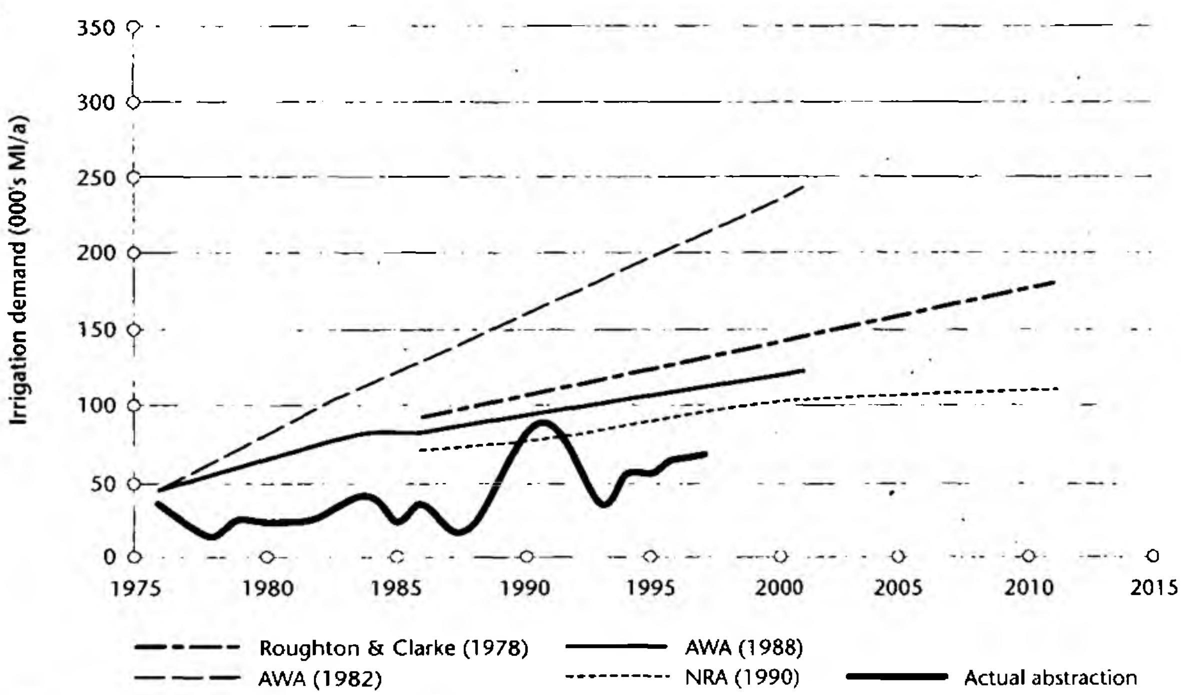
2.1 Previous forecasts

In developing our water demand scenarios we draw on the long tradition of forecasting within water resources planning. Since the forecasts prepared by the Water Resources Board in the 1960s, the robustness of forecast data and methods have significantly improved. Understanding the relative importance of the different components of water demand has also progressed and today, public water supply forecasts routinely break down demand into seven components (UKWIR/NRA, 1995), and explicitly include leakage. Data sets related to the components of demand are also becoming more robust. Water companies routinely monitor the consumption of their large industrial customers, and most have set up household water consumption monitors. These provide detailed information from a cross section of household customers, and in some cases provide a measure of the different uses of water within the home.

Improvements in the availability and reliability of data sets have encouraged the development and application of more sophisticated forecast methods. Any assessment of previous public water supply forecasts must take into account the influence of such changes. Rather than simply extrapolating past trends, the water industry is now applying econometric and micro-component methods. The UKWIR/NRA (1995) *Demand Forecasting Methodology* assesses the relative advantages and disadvantages of a range of methods for projecting household and non-household demand. It also recommends an approach to leakage.

The robustness of forecast methods and assumptions is also important when assessing spray irrigation demand forecasts. For example, a number of forecasts were carried out for East Anglia, the region with the highest concentration of spray irrigation in England and Wales. These forecasts only partially considered the effects of seasonal weather patterns, changes in the external economic and agricultural policy regime and the effects of non-availability of water (Roughton and Clarke, 1978; Anglian Water Authority, 1982, 1988; NRA, 1990). Some of them failed to distinguish between different irrigated crops, or to set sensible limits for the total crop area or the proportion of each crop that would be irrigated. Given that many of the forecasts were commissioned following periods of drought when interest in irrigation was abnormally high, the subsequent forecasts significantly over-estimate the rate of growth in demand (Figure 2.1).

Figure 2.1 **Comparison of regional spray irrigation forecasts – East Anglia**



All forecasts merely represent a "snapshot" assessment of "likely" rates of change on the basis of the Government policies, social attitudes and levels of affluence prevalent at the time. Traditionally, water demand forecasts reflect a very narrow perspective on social and economic change, largely adopting a "business as usual" assessment of likely developments. Comparisons of forecast against actual demands demonstrate, however, that the reality is often far more complex, since unforeseen social, economic and political changes undoubtedly have an effect. Three examples demonstrate this influence. The first example relates to forecasts of industrial and commercial demand made in the early 1970s compared with actual out-turn. The forecast rates of growth have failed to materialise, and some schemes based on these projections are still not fully utilised. The economic recession and restructuring of the UK industrial base that occurred throughout the late 1970s and 1980s significantly reduced demand for water.

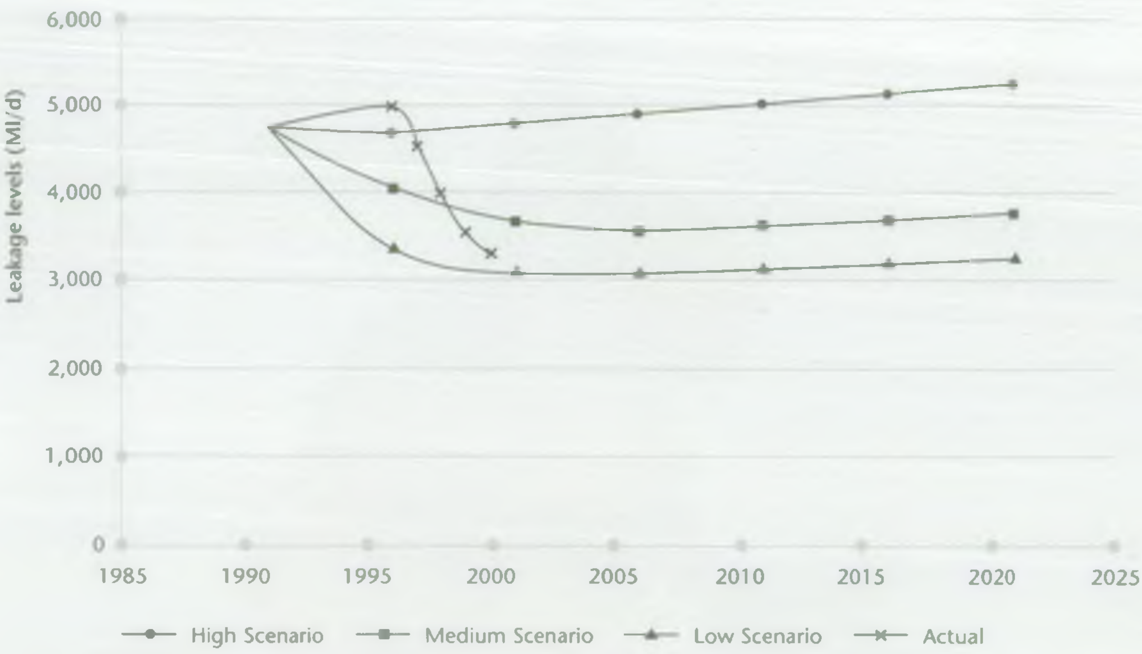
The second example relates to changes in public perception of leakage. The forecasts presented in the NRA document *Water: Nature's Precious Resource* (1994) projected three levels of leakage related to high, medium and low demand scenarios (Figure 2.2). Although these leakage levels were perceived as challenging at the time, they were believed to be "well within the aspirations of most water companies". The drought of 1995 challenged the prevailing attitude to leakage control, with politicians, the public and regulators demanding greater action. This culminated in the 1997 Water Summit that established the principle of mandatory leakage targets (DETR, 1997). Comparison of the NRA (1994) leakage forecasts against actual leakage levels demonstrates the effects of these changes, with leakage now close to the low forecast.

The final example of the influence of socio-economic change on the use and management of water relates to spray irrigation demand. Since the first national spray irrigation forecast in 1980 (ACAH, 1980), experience has demonstrated that irrigation demand is linked to the profitability and viability of different sectors and sub-sectors of agriculture. The high levels of growth predicted in 1980 have failed to materialise, partly because changes in the dairy industry have realigned the economics of grassland irrigation.

In developing long-term forecasts, the one element of certainty is that they will be proved wrong. Comparing previous forecasts against actual demand demonstrates that unforeseen social, economic and political changes can have unexpected consequences for the way in which water is used and managed within the home, and in industry, commerce and agriculture. Often the level of projected demand has been overestimated, with actual demand significantly below forecast levels.

Social, economic and political changes can combine in a number of ways to give a range of possible water demands. To track the effects of these different combinations on the use and management of water, we

Figure 2.2 Comparison of projected and actual leakage levels 1990-2021



have developed scenarios that encompass social values and systems of governance and allow us to consider explicitly a range of possible social, economic and political changes. Adoption of a scenario-based approach further reinforces the evident inflexibility of the old "predict and provide" doctrine, which involved developing resources to meet all possible future demands. By considering different possible futures, we can develop an approach that involves different ways of managing water use and expectations to produce a strategy that is robust and flexible.

2.2 Water company water resources plans

In April 1999 water companies submitted their water resources plans to the Environment Agency. These plans provide a breakdown of future demands and available resources at resource zone level. As a basis for water supply planning, zones are defined as the largest area in which all resources can be shared to ensure that all customers experience the same risk of supply failure from a resource shortfall. The size of resource zones varies quite markedly across England and Wales (Figure 2.3).

Included within the water resources plans are resource zone forecasts of total demands from 1997/98 to 2025. These forecasts generally applied "best practice" forecasting methods and included up-to-date information sources. The data used in these forecasts varied between companies, both in terms of its quality and applicability (Environment Agency, 1998a; Environment Agency, 1999).

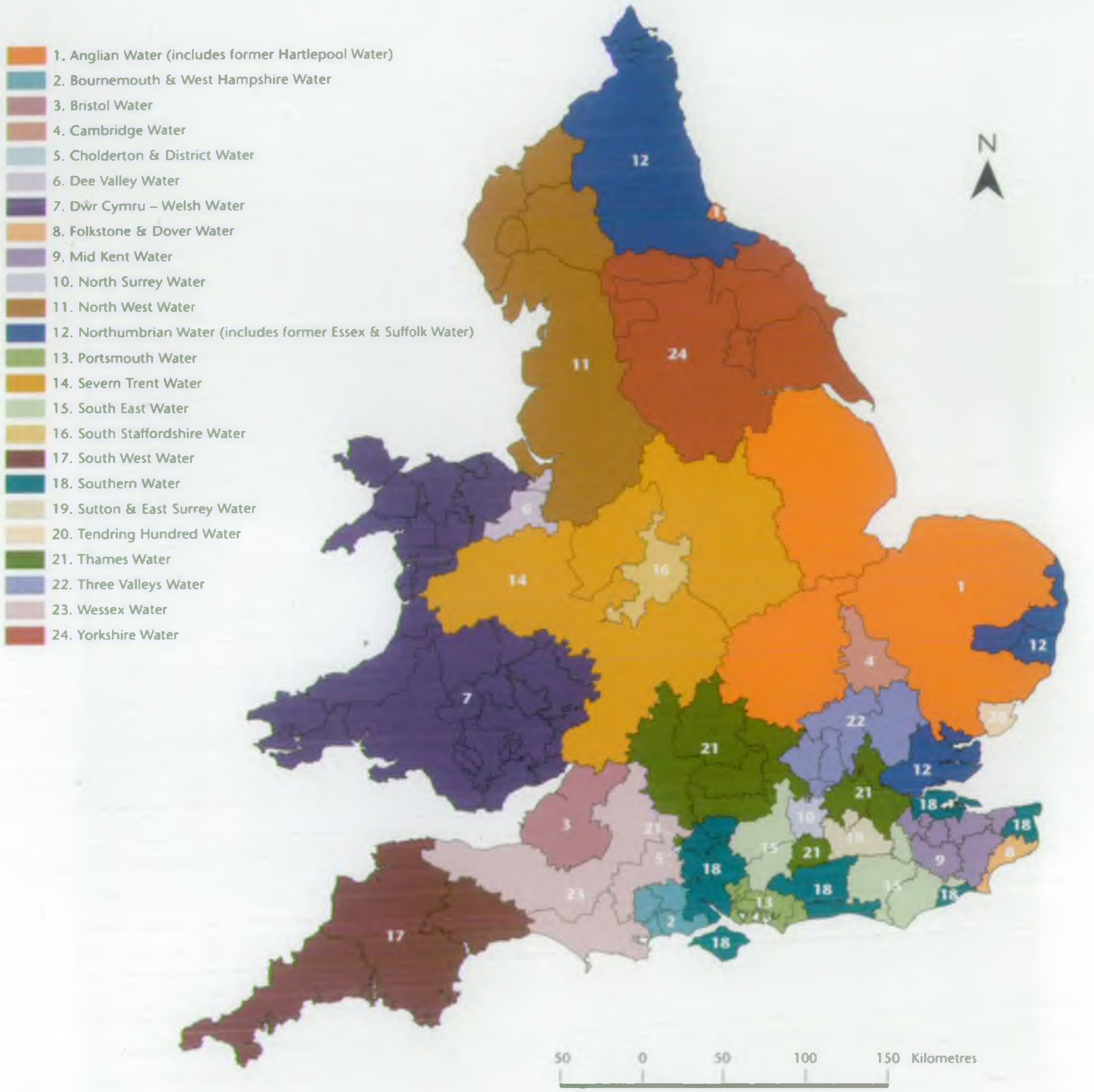
Monitors of household consumption influence estimates of resource zone per capita consumption. The quality of data emerging from these consumption monitors varies in relation to the type of monitoring programme, the size of the household sample, its applicability to each resource zone and length of record. Some water companies have developed their own consumption monitors; others apply the results of another company's consumption monitor to their own data. In these circumstances, "best practice" indicates that the data are adjusted to reflect specific population characteristics of each region. The Agency will continue to work with water companies to ensure that they use best estimates of household consumption in their forecasts.

The variability in per capita consumption was identified as a key issue arising from the draft plans submitted in 1998 (Environment Agency, 1998a) and in the subsequent 1999 submissions (Figure 2.4).

In our forecasts we have referred to information from the water resources plans relating to:

- measured and unmeasured household per capita consumption (pcc) in litres/head/day (l/h/d);
- measured and unmeasured household and population numbers;

Figure 2.3 **Water company resource zone boundaries**



- total leakage in megalitres/day (Ml/d);
- non-household: total demand (Ml/d);
- distribution system operational use (DSOU) and water taken unbilled.

For the DSOU and water taken unbilled components, we have used the water company reported values across the planning period.

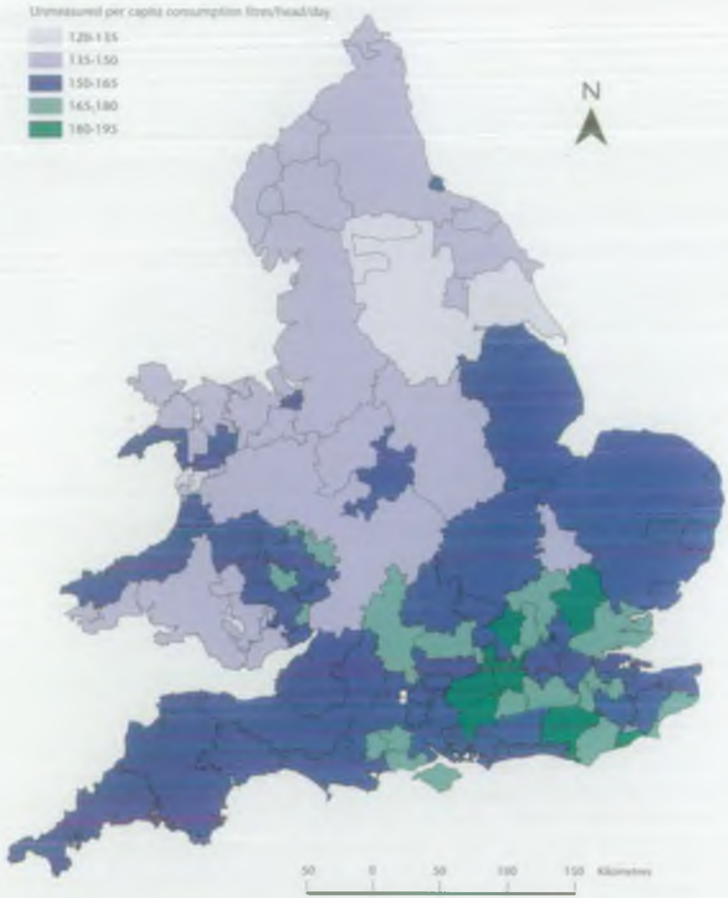
2.3

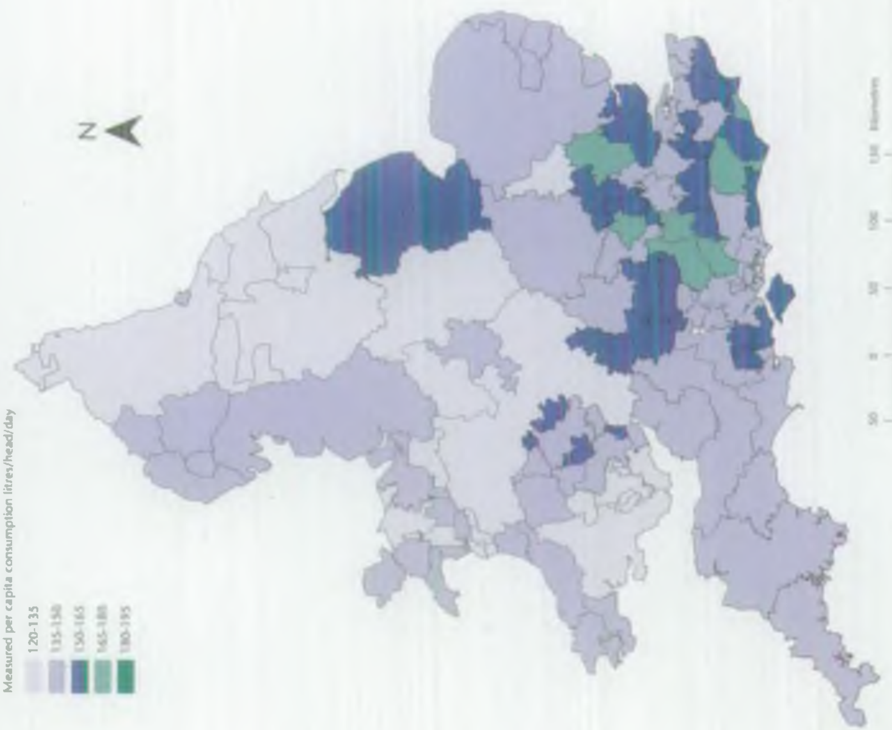
Drivers of component demand

Many of the key drivers of component demand are already recognised within the wider water industry and literature. For the purposes of this analysis we have drawn a distinction between:

- those areas of policy and regulation that directly relate to the use and management of water;
- those factors that indirectly influence demand within the home or within a specific sector.

Figure 2.4 Resource zone unmeasured and measured per capita consumption 1997/98




N
Measured per capita consumption litres/head/day
120-135
135-150
150-165
165-180
180-195

The water abstraction licensing system, cost of water, water regulations, and metering directly affect the use and management of water by water companies, individuals, farmers, industry and commerce. However, within industry, commerce and agriculture, water represents one input into complex systems of production. The over-riding factors determining the level of water use relate to sector specific regulations, policies and market forces of competition that directly shape production decision-making. Within industry, therefore, changes in the level of economic growth or interest rates will affect the demand for goods and therefore the level of production. This in turn will determine the level of water consumption.

To assess the impact of socio-economic change on the key drivers of component demand, we have classified the drivers into three distinct groups (Table 2.1):

- water policy drivers – which directly regulate the use and management of water within the water company, home, industry, commerce or agriculture;
- technology drivers – related to specific water-using equipment and appliances within the home, industry, commerce or agriculture;
- sector specific drivers – related to specific policies and regulations within industry, commerce and agriculture that determine the type and level of production.

For all components of demand there is one over-arching driver, which relates to the level of economic growth and affluence. This influences not only the purchase of water-using appliances within the home, but also the level of output and employment within industry and commerce and consumer demand for fruit and vegetable produce.

In the following sections we draw on this classification in our assessment of the key drivers of component demand, which is summarised in Table 2.2.

2.3.1 The drivers of household demand

The drivers of household demand relate to two interlinked sets of information, which together make up household demand forecasts:

- population and household numbers;
- per capita consumption (pcc) estimates.

The annual growth rate of the population in England and Wales has remained relatively constant over the last 20 years. Although the birth rate has been declining, this has been offset by an increased life expectancy. Government population projections over the next 20 years or so reflect these historic trends. In our water demand forecasts we assume that the demographic effects of scenarios start to become apparent only after 2010. Over the forecast period, scenario-specific changes to the population profile will influence only that portion of the population born in the 15-year period between 2010 and 2025. This means that the overall effect of the different scenarios on the total population in 2025 is small.

The geographic location of new housing developments also plays an important role. According to the latest Government projections the number of new homes in England and Wales is to increase by 3.3 million between 1996 and 2016. This is largely due to the trend towards smaller household size. The location of this growth is still subject to negotiation between the Government, regional development agencies and local authority planning departments. The relative economic success of different locations will also play an important role. This is a subject area that we will keep under review as decisions are made by the planning bodies.

To address these issues, we have used a nationally consistent projection of population and household numbers for each water company resource zone for the period from 1997 to 2019, extrapolated to 2025. This reflects the 1996 population projection (using 1991 census information), adjusted to incorporate 1997 mid-year estimates. These projections reflect recent historic trends in births, deaths and migration. We have assumed that the population profile remains relatively stable over the planning period. Hence we have not applied assumptions related to the Foresight "Environmental Futures" framework to the population and household drivers of household water demand. Our analysis has concentrated on the drivers of per capita consumption.

Economic affluence is a key driver of pcc. The rate at which householders replace their water-using appliances or purchase appliances that are newly available will depend to a large extent on their disposable income. Affluence also influences some of the key behavioural drivers of water use. The preferences, values and aspirations of individuals and groups in society will influence the patterns and types of personal water use. For example, personal washing will reflect individual preferences for showering or bathing, while the level of household affluence will partly influence the type of shower installed.

The key water policy drivers of pcc relate to household metering and water regulations. Household metering

Table 2.1 Examples of some of the key drivers of component demand

Water policy drivers	Technology drivers	Sector-specific drivers
• abstraction licensing • water price • water regulation • metering • leakage targets • levels of service • water efficiency duty	• white goods • power showers • acoustic loggers • industrial reuse and recycling equipment • irrigation scheduling systems • trickle irrigation	• Common Agricultural Policy (CAP) • supermarket produce quality criteria • rate of uptake of water-use minimisation measures by industry and commerce

Table 2.2 Summary of the key drivers of component demand

Component of demand	Driver classification	Driver
Household demand	Water policy driver	• Metering • Water Regulations
	Technology driver	• White goods • Miscellaneous
	Behavioural driver	• Type and pattern of personal washing • Garden watering
	Economic driver	• Personal affluence
Leakage	Water policy driver	• Regulatory framework • Resource stress
Industrial & commercial demand	Economic driver	• Level of output from manufacturing based industries • Level of employment within service based industries
	Sector specific policy driver	• Rate of uptake of water-use minimisation
	Technology driver	• Replacement of process equipment
Spray irrigation demand	Sector specific policy driver	• National and international agricultural price support schemes • Organic production • Role of supermarkets and food processing firms • Drought tolerant crop varieties
	Technology driver	• Relative efficiency of irrigation equipment and scheduling systems

encourages people to consider their use of water, partly by allowing them to understand how much water they are using. It raises awareness directly, when the bill arrives. Provided that appropriate tariffs are charged, metering of households encourages high users of water to reduce their water use. In the longer term, it should lead to changes in attitude, so that, for example, when new appliances or bathrooms are purchased, people will choose devices that are water-efficient. The Water Supply (Water Fittings) Regulations 1999 provide a legal limit on the water consumption of devices and appliances. These regulations are set by government but enforced by water companies. While these have been set within the context of the European single market, they play an important role in water efficiency.

The current regulations ensure that all new toilets comply with a maximum single flush volume of 6 litres from 1 January 2001.

The technological drivers of household demand relate to all water-using appliances within the household. The frequency and volume of use of each appliance critically affects household consumption. Over time, technological innovation is improving the efficiency of many appliances, reducing the volume of water per use. This will have a particular effect on white goods such as washing machines and dishwashers, which together form a large proportion (22 per cent) of household water use.

2.3.2 The drivers of leakage

All water distribution systems leak from cracks, holes and joints in the pipe network. Leaks are caused by the deterioration of the mains network, principally due to ageing but exacerbated by factors such as traffic loading, ground movement, aggressive soils, freeze-thaw and corrosive water. The level of leakage is a function of the number of leaks and bursts and the "run time" before they are repaired. For the leakage component we have drawn a distinction between those drivers relating to the operational management of leakage, and the water policy drivers defining the regulatory framework which set water company levels of investment and leakage targets. In practice, these policy drivers set the framework within which water companies determine the operational management of their distribution network.

The price determination process drives the system of economic regulation within which water companies operate. This sets the level of water company investment over a five-year period, which determines the level of investment in leakage control methods such as mains replacement, pressure management or leakage detection equipment and repair.

The second policy driver relates to the annual leakage targets set for all water companies in England and Wales by Ofwat. Current targets are set on the basis of either the water company's assessment of the economics of leakage control or, where this is not considered to be robust, on the company's relative resource position and existing levels of leakage. Those companies with greater water scarcity are expected to make greater reductions in leakage.

2.3.3 The drivers of industrial and commercial demand

The key drivers of industrial and commercial demand for water relate to the drivers of the UK economy. The level of economic growth (Gross Domestic Product GDP) is in part determined by the level of output and employment within UK businesses, which reflects the structure of the economy and the relative balance between manufacturing and service-based industries. The intensity of water use varies quite markedly between service and manufacturing-based industries. Within service industries, demand for water varies in relation to the numbers employed, whereas within production-based industries water demand varies in relation to the level of output (UKWIR/Environment Agency, 1997).

The second set of drivers relates to the technology used within the industrial process. It is assumed that over time technological innovation will improve the design and productive efficiency of equipment. Potentially, replacing equipment with more water-efficient technology will reduce the demand for water.

Published UK evidence on these relationships is extremely sparse, with Rees (1969), Herrington (1972) and Thackray and Archibald (1981) providing the most detailed analyses of the factors influencing demand for water. Significant changes, not only in the structure of the UK industrial base but also in the form of water regulation, mean that these studies are of limited use in explaining current and future patterns of water demand.

A third set of drivers relates to the implementation of waste and water-use minimisation initiatives. The benefits of water-use minimisation within industry and commerce have been well documented, with 125 demonstration projects and clubs established across England and Wales. Many studies, including those by Envirowise (formerly Environmental Technology Best Practice Programme) and the Environment Agency, have demonstrated the scope for reducing water consumption and the considerable cost savings. Despite this, the level of uptake of water-use minimisation remains disappointing.

The literature identifies a reluctance in many firms to implement waste and water-use minimisation measures (Baylis *et al*, 1997, 1998a, 1998b; Gouldson and Murphy, 1997, 1998; Hillary, 1999). Large firms and Small and Medium Enterprises (SMEs) differ markedly in their willingness and ability to implement waste and water-use minimisation measures. Many studies identify barriers to uptake which reflect:

- the low value placed on water by businesses;
- the lack of organisational and managerial commitment to the environmental agenda;
- the difficulty in persuading management to allocate money and manpower to water-use minimisation initiatives.

2.3.4 The drivers of spray irrigation demand

Agriculture is subject to a wide range of social, economic and political policy drivers. Their influence on spray irrigation demand is variable. Irrigated crops in England and Wales largely fall outside the agricultural price support system. This means that reforms introduced through the Common Agricultural Policy (CAP) and World Trade Organisation (WTO) have only an indirect effect on spray irrigation demand. The implementation of such reform will indirectly shape farmers' perception of risk and uncertainty, which in turn will influence the allocation of resources to each enterprise. International reforms introduced through the World Trade Organisation (WTO) directly influence world commodity prices. In particular this will affect UK sugar beet production.

The UK Government has set up a system of grant aid to encourage farmers to switch to organic systems of production. The implications of this for spray irrigation are still subject to some debate. Since organic crops require a larger area of land to match yields achieved by conventional systems, the area irrigated could increase. However, the depth of irrigation water applied is less certain. Organic production methods place great emphasis on improving the natural productivity of the soil, through a number of land management techniques. Some of these improve the moisture retention capacity of the soil, which means that less water will need to be applied through irrigation.

The final set of sector-specific policy drivers relates to the sourcing policies of supermarkets and food processing firms. Through the specification of Integrated Crop Management (ICM) protocols and Assured Farm Produce Schemes, supermarkets and food processing firms set strict produce quality criteria. Failure to meet these specifications can result in significant financial losses. A shift has thus occurred away from irrigation purely for crop yield, towards greater emphasis on crop quality.

A key driver of spray irrigation demand is the susceptibility of different crop varieties to water stress and drought. Of particular importance is the susceptibility of different potato varieties to water stress. Currently, a number of varieties combine tolerance to water stress with a low susceptibility to common scab, even though they are often not included on the "preferred variety" listings of supermarkets and food processing firms. Farmers are therefore discouraged from growing them, and remain vulnerable to reduced quality and quantity of the crop in periods of low rainfall.

The technological drivers of spray irrigation demand relate to scheduling systems and irrigation equipment. Hose reel irrigators are most common in England and Wales. The relative application efficiency of these systems can vary quite considerably without careful management. Technological innovation may result in the development of more efficient system, but their capital and operating costs will play an important role in determining the rate of investment by farmers.

2.3.5 Summary

In this chapter we have identified the key drivers of component demand and their sensitivity to socio-economic change. We draw on this analysis as we develop component-based water demand scenarios related to the Foresight "Environmental Futures". In Chapter 3 we set out the Foresight "Environmental Futures" framework approach and the principles that underpin the application of this framework to the components of water demand.

3 The Foresight "Environmental Futures" framework

This chapter outlines how we have applied the Foresight "Environmental Futures" framework to the different components of water use to develop specific water demand scenarios. The chapter is divided into two sections. Section 3.1 describes the Foresight "Environmental Futures" framework and how the key dimensions of social values and systems of governance are used to define four scenarios of future social development. Section 3.2 focuses on the key principles underpinning our application of the Foresight framework to the key drivers of component water demand.

3.1 The Foresight "Environmental Futures" framework

The Foresight programme, sponsored by the Department of Trade and Industry (DTI), sets out to identify innovative market opportunities and new technologies that will enhance the competitive advantage of businesses in the UK. In 1999, the Energy and Natural Environment Panel published a set of scenarios focused on the environment (DTI, 1999). These are intended to inform and stimulate debate among businesses, regulators and government departments about the environment, and encourage them to develop strategies and policies that will prove robust to a range of "possible environmental futures".

The scenarios use two core dimensions of social change: social values and systems of governance. These dimensions are used as axes, to define four scenarios (Figure 3.1), which describe the UK during the period 2010-2040.

Social values – on the horizontal axis, these reflect policy-making priorities, political preferences and patterns of economic development. At one end of the spectrum social values are dominated by *consumerist* attitudes which emphasise individualism, materialism and private consumption. Concern for the environment focuses on specific problems that impact on the individual or their immediate local area. In contrast, *community*-orientated values are concerned with securing long-term social goals such as equity and sustainable economic development. There is a strong emphasis on the enhancement of collective goods and services, reflected in the high priority placed on the use of resources and environmental problems.

Systems of governance – the vertical axis represents the structure of political authority and decision making. *Globalisation* is characterised by the redistribution of political power and influence away from the nation state towards pan-European and global institutions such as the United Nations (UN) and World Trade Organisation (WTO). Economic activity is locked into international trading systems, dominated by trans-national corporations. This is distinct from *regionalisation*, where national sovereignty is strengthened and there is a movement towards regional devolution and local government.

Using the pressure–state–response model of environmental change, a story line is developed of the key drivers of social, economic, political and technological change under each scenario. At a broad scale, this involves assessing the level of economic growth and structure of the economy. The degree to which environmental issues are prioritised by policy makers, businesses, farmers and individuals is

Figure 3.1 The Foresight "Environmental Futures" scenarios

considered, along with a review of the state of the environment. In some cases indicators are included to illustrate the direction and rate of change under each scenario (Table 3.1). In the context of water resources, the Foresight "Environmental Futures" framework provides high-level assessment of water demand as increasing, decreasing or stabilising and broad qualitative indicators of the level of leakage, meter penetration and water efficiency.

In broad terms the four scenarios can be characterised as:

- **Provincial Enterprise Scenario:** a future in which the nation state disengages from international political and economic systems of governance. This is a low growth, low wage and low investment scenario with little concern for social equity. The environment is perceived as a low priority issue despite the increased pressures placed on natural resources.
- **World Markets Scenario:** a future in which a highly developed and integrated world trading system generates high levels of economic growth. Although personal affluence rises, there is little concern for social equity. Awareness and concern for the environment is low, particularly among the less well off.
- **Global Sustainability Scenario:** a future where global institutions play a central role resolving social and environmental problems. High levels of investment in research and development result in the development of innovative clean technologies that benefit the environment.
- **Local Stewardship Scenario:** a future dominated by regional and local systems of government. Working at the local level, environmental problems are resolved through collective action.

The Foresight scenarios are not intended to be predictions of the future; instead they provide an indication of alternative patterns of social development and highlight the consequences for the use and management of the environment. All of the scenarios represent possible "Environmental Futures"on the basis of where we are today.

3.1.1 The processes of state and market regulation

The "Environmental Futures" framework provides a broad indication of the social, political and economic context within which markets, regulations and behaviours will develop and evolve. The accompanying story lines also provide insight into the processes of state and market regulation that will influence and shape the decision-making of policy makers, individuals, farmers and businesses. Central to our application of the "Environmental Futures" framework to the components of water demand is recognition that different mechanisms of state and market regulation will influence decision-making within each scenario (Table 3.2). For example, deregulation predominates under the World Markets Scenario, and direct state environmental regulations are reformed and repealed to ease the burden on business. These are replaced by economic incentives such as tradable permits, which are used to control the use and management of natural resources.

Table 3.1 Foresight scenario characteristics

	Provincial Enterprise	World Markets	Global Sustainability	Local Stewardship
Values	Individualist	Consumerist	Conservationist	Conservative
Governance	National	Globalised	Globalised	Regional/national
UK GDP (pa)	1.5%	3%	2%	1%
Equity	Declines	Declines	Improves	Improves
Fast growing sectors	Private health care and education, maintenance services	Health care, leisure, financial services	Business services, IT, household services	Small-scale intensive manufacturing, locally based financial and other services, small-scale agriculture
Declining sectors	High-tech specialised services, financial services	Manufacturing, agriculture	Resource intensive agriculture and manufacturing	Retailing, leisure and tourism
Water demand	Stable	Increase	Decline	Decline
Leakage	Low levels of investment in the water industry means that leakage levels are relatively high	-	-	Aggressive campaigns to reduce water leakage
Water efficiency	-	Implementation of low cost measures	Improved domestic water efficiency	Successful
Environmental issues and priorities	Low priority placed on the environment. Low levels of investment create significant environmental problems	Environmental improvement not a priority. Emphasis on issues which impact on the individual or local area	Sustainable development accorded high political priority. Resource use efficiency drives policy	Sustainable development closely integrated into all areas of decision making. Effective community action resolves local environmental problems

Source: DTI, (March 1999) Environmental Futures, Office of Science and Technology, London

Table 3.2 Matrix of state and market forces of regulation influencing decision-making

	Provincial Enterprise	World Markets	Global Sustainability	Local Stewardship
State:				
• Regulations and directives enshrined in UK law;	✓✓	✓	✓✓✓✓✓	✓✓✓
• Economic incentives - taxes, tradable permits, incentive charging.	✓✓✓	✓✓✓✓✓	✓✓✓	✓✓
Market:				
• Supplier contract conditions	✓✓✓✓	✓✓✓✓	✓✓✓	✓✓
• Voluntary agreements	✓✓	✓✓✓	✓✓✓✓✓	✓✓✓
State & Market:				
• Education	✓✓	✓✓	✓✓✓	✓✓✓✓✓
• Public information campaigns	✓	✓✓	✓✓✓✓✓	✓✓✓✓✓
• Market advertising	✓✓✓✓	✓✓✓✓✓	✓✓✓	✓
• Membership of voluntary environmental groups	✓	✓✓	✓✓✓	✓✓✓✓✓

Key: ✓ = low level of influence; ✓✓✓✓✓ = high level of influence

Under the Provincial Enterprise Scenario the low priority placed on the environment inhibits the effectiveness of all forms of market and state regulation. The sustainable management of natural resources and the environment in this scenario is very difficult.

By explicitly identifying the mix of state and market regulations within each scenario, we are able to ensure consistency in our application of the "Environmental Futures" framework to each component of water demand.

3.1.2 Relationship between Foresight and UKCIP socio-economic scenarios

The UK Climate Impacts Programme (UKCIP) has developed socio-economic scenarios for use in climate change impact assessment (UKCIP, 2000). These scenarios aim to describe the social, economic and political framework within which climate change adaptation strategies might develop in the UK in the 2020s and 2050s. The UKCIP approach uses, as its starting point, the Foresight "Environmental Futures" scenarios (DTI, 1999), which have been further developed to sharpen their relevance to climate impact assessment. This has been achieved through a process of consultation with policy makers, stakeholders and climate impact researchers, as well as the development of quantitative indicators. These indicators are used to illustrate scenario story lines and for input into integrated climate impact models.

In line with Foresight, the UKCIP scenarios use the core dimensions of social values and systems of governance to define four possible futures. The main difference relates to the renaming of the Foresight "Provincial Enterprise" scenario as "National Enterprise"; the integrity of the story line remains. Our water demand scenarios are consistent with both these approaches. The quantitative indicators (UKCIP, 2000) provide a greater level of detail. Of particular relevance to future revisions of the water demand scenarios are those indicators related to population, household numbers and average household size.

3.2 The Foresight "Environmental Futures" framework and water demand

The Foresight scenarios are intended to define a broad contextual framework of social, economic, political and technological change. Assessment of the impact of these processes on specific sectors of the economy or particular aspects of the environment are deliberately general, with the intention that other experts would add to the framework to develop coherent sector-specific scenarios. We have taken the "Environmental Futures" framework as our starting point for the development of specific water demand scenarios. Although the resulting scenarios are derived from foresight, they are not part of the Foresight programme itself. For this reason, we have named our scenarios Alpha, Beta, Gamma and Delta as follows:

- Provincial Enterprise – Scenario Alpha
- World Markets – Scenario Beta
- Global Sustainability – Scenario Gamma
- Local Stewardship – Scenario Delta

3.2.1 Application of the "Environmental Futures" framework to the drivers of water demand

Rather than develop specific forecast models tailored to each scenario, we have taken as our starting point the key drivers of demand specified in Section 2.3. We have assumed that these drivers remain consistent across all scenarios. This enables us to develop a core-forecast model related to each component, designed to allow the application of scenario-specific assumptions to each driver of demand.

In linking the drivers of demand to the Foresight framework, we have drawn on information in Berkhout *et al* (1998) to assess the relative impact of the scenarios on each driver of demand Table 3.3). Appendix 1 summarises this assessment. For some drivers of household demand and leakage we have had to draw our own inferences of the impact of a particular scenario (this is highlighted in italics in Appendix 1). In doing this we have retained consistency with the scenario story line, associated indicators and the matrix of state and market regulation.

3.2.2 Timing of scenario assumptions

A critical issue underpinning all the forecasts is the timing of assumptions related to the four scenarios. Although all scenarios are equally likely, based on current values, policies and regulations, the transition to each scenario is likely to be variable. Fundamental changes in social attitudes, structure of government and policy priorities will not be immediate. We have assumed that although such changes will start to evolve from today, the consequences will only start to become apparent in the demand forecasts between 2005 and 2010. By 2010 the impact of the changes are relatively small; in 2025 the differences are quite large. The variable timing in part reflects differences between the scenarios, and also the magnitude of the changes

Table 3.3 Assessment of influence of each scenario on the key drivers of demand

Component	Driver of demand	Influence by scenario			
		Alpha	Beta	Gamma	Delta
All components	Cost of water	Very high	High	Medium	Medium
Household demand	Changes to personal washing use Garden watering Miscellaneous	Large increase Increase Moderate decline	Large increase Increase High growth	Small decline Slow decline High growth	Small decline Moderate decline Moderate decline
	Efficient technology (white goods)	Small decrease	Moderate increase	Increase	Increase
	Regulations particularly effects on WC cistern volumes, power showers and garden watering	Slow decline	Decline	Rapid decline to low volume flush WC	Slow decline to low volume flush WC
	Metering	Very variable locally	Moderate	High	Moderate
Leakage	Regulatory framework	Weak	Light	Strong	Conservation-orientated
	Resource situation	Not considered	Important	Important	Secondary consideration
Industry and commerce	Economic growth (GDP) Output of manufacturing industries Employment in business services Water-use minimisation activity Greening of business initiatives	1.5% Increase Decline Low Low	3% Decline Increase Mixed Low	2% Decline Increase High High	1% Decline Increase High High
Spray Irrigation	Reform of national and international agricultural policies (CAP & WTO)	Increase UK Government support	Removal	Full reform	Increase national and regional support
	Role of supermarkets & food processing firms	Continued role	Expansion	Realign position	Marginal role
	Crop quality premia (potatoes) Drought tolerant crop varieties Organic production Irrigation efficiency	High Low uptake Low Medium	Very high Low uptake Low High	Medium Very high uptake High Very high	Low High uptake Very high High

implied compared with our current position. Even on this basis, the outcomes will never be fully developed as the scenarios merely represent stages on the way to somewhere else.

For each component we have looked at the drivers of demand and considered how each of these will vary under the four scenarios. The starting point for each scenario is the same. The technologies and policies included within the four scenarios are all available within the UK or overseas today. Hence the assumptions are within present bounds of possibility and represent a realistic assessment of likely change. However, the combination of factors leading to each scenario is only one way that these results could arise. The development of society and government systems is complex, and our four scenarios represent only four possible snapshots of the future. It is most likely that the future will follow some other path, combining some factors from each of our scenarios, and some aspects that we have not considered. By considering this range of scenarios, we have dealt with most of the possible range of conditions that could happen.

4 The household demand scenarios

Forecasts of household demand for water have been developed for each water company in England and Wales at the resource zone level. We have drawn on information supplied by water companies in their water resources plans to develop a nationally consistent data set. From this we have projected unmeasured and measured per capita consumption for each of the 125 resource zones of England and Wales.

This chapter is divided into six sections. Section 4.1 sets out our forecasting method, outlining how a micro-component approach allows us to link the drivers of household demand to the Foresight framework. Three elements generate total household demand: unmeasured per capita consumption, measured per capita consumption and population forecasts. Sections 4.2 to 4.4 address each of these elements in turn, setting out the key issues related to the generation of both base-year information and the development of scenario-specific forecast assumptions. In Section 4.5 we draw these elements together in the generation of total household demand. The final section, 4.6, presents the outcomes of the total household demand scenarios in 2010 and 2025.

4.1 Forecasting household demand

Forecasts of total household demand are principally made up of two interlinked sets of information:

- estimates of per capita consumption (pcc);
- forecasts of population.

In developing demand scenarios related to the Foresight framework we have separated out the development of assumptions related to unmeasured and measured per capita consumption. As we explained in Chapter 2, we have not applied Foresight-related assumptions to population projections.

Several forecast methods are suitable for projecting household per capita consumption. These range from simple trend analysis and percentage growth factors to detailed micro-components analysis (UKWIR/NRA, 1995; UKWIR/Environment Agency, 1997). Some of these methods would not be appropriate for forecasting household demand using the Foresight framework. For example, trend analysis assumes that the past is a good indicator of the future. This is not a suitable basis for considering the effects of four different scenarios of social values and systems of governance on household water use.

4.1.1 A micro-component approach to forecasting household demand

We have identified micro-component analysis as the most appropriate way of linking the drivers of household demand to the Foresight framework. Breaking down the use of water in the home into its constituent uses, such as toilet flushing or dish washing allows us to consider the effects of changes in social values, regulations, policy and technology on the drivers of each micro-component.

Micro-component analysis breaks down household water use into discrete uses, isolating particular tasks or appliances and determining the water-using characteristics of each. In line with Herrington (1996) we have identified eight broad categories of household water use (Figure 4.1), which we further sub-divide into 14 micro-components (Table 4.1). This sub-division was informed by our analysis of the micro-components used by water companies.

The categorisation reflects changes in regulation and the emergence of new water-using equipment. For example, the toilet micro-component takes into account

Figure 4.1 The eight categories of household water use 1997/98 (litres/head/day)

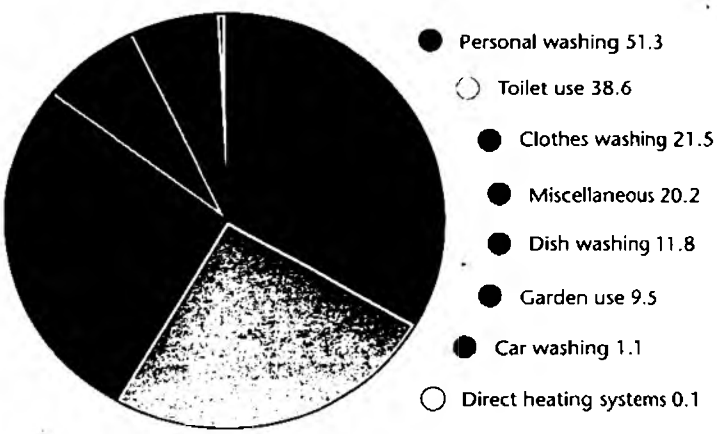


Table 4.1 The micro-components of household water use

Household water use components	Micro-components
Toilet use	WC
Personal washing	Bath Shower Power shower Hand basin
Clothes washing	Washing machine Clothes washing by hand
Dish washing	Dish washer Dish washing by hand
Car washing	Car washing
Garden watering	Sprinkler Other garden watering
Direct heating systems	Combination boiler
Miscellaneous	Miscellaneous

the effects of the Water Supply (Water Fittings) Regulations 1999 on cistern flush volumes. From 2001, maximum cistern volumes for single-flush toilets are set at 6 litres; dual-flush toilets are set at a maximum of two-thirds of the full-flush volume. In 1996 waste disposal units were perceived as a potential growth area in household water use. However, consultation with a number of house builders, Herrington (1999) and evidence from the water resources plans suggests that this projected growth has failed to materialise. We have therefore subsumed this use within the miscellaneous category. Conversely, to reflect the increasing popularity of energy-efficient direct heating systems we have separated this use from miscellaneous. Compared with conventional water-heating systems, water must be run off before the heating device reaches the required temperature. Hence we have considered the use of direct heating systems explicitly. In our analysis, miscellaneous use includes filling swimming pools and ponds, as well as those numerous but small indoor tap uses such as cooking, cleaning, and watering house-plants. We have also included other water-using devices such as pressure washers and waste disposal units.

Each micro-component is determined by three factors:

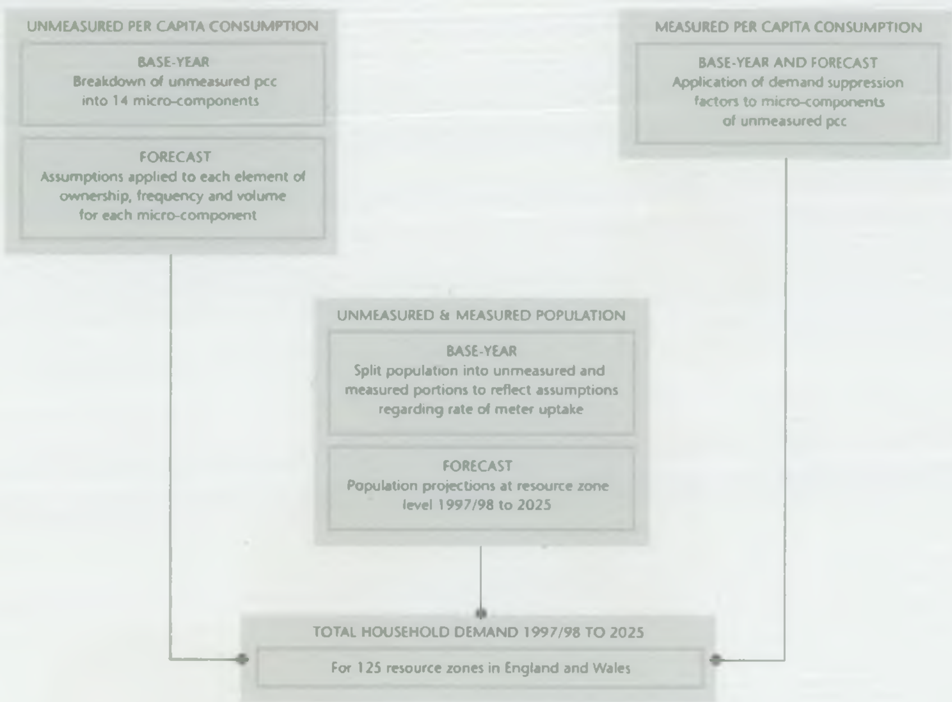
- **ownership levels (O)** – of an appliance or extent of activity, as a proportion of either the population or household stock;
- **frequency of use (F)** – per person or household per day, week or year;
- **volume of water per use (V)**, in litres.

The majority of micro-components can be quantified in this way. Miscellaneous use requires a different approach however, since it comprises elements of consumption that prove difficult to quantify in terms of ownership, frequency of use or volume. We have assumed that miscellaneous use increases at the same proportionate rate as the remaining micro-components.

4.1.2 Forecast method

The standard approach to micro-component-based forecasting is to generate OFV values for each micro-component in the base-year (UKWIR/NRA, 1995; UKWIR/Environment Agency, 1997). We can use a combination of information on consumption from specific water companies and secondary sources such as Herrington (1996) and *Regional Trends* (ONS, 1999). We then apply forecast assumptions specifically to each of the O, F and V elements related to each micro-component. When multiplied, these generate a pcc value for each micro-component. In turn, these are added together to give an overall pcc value related to each forecast period.

Figure 4.2 The household demand forecast process



$$\text{pcc (litres/head/day)} = \sum_{i=1}^{n} (O_i \times F_i \times V_i) + mu$$

where:

n = number of micro-components specified

O_i = proportion of population or households using appliance, or undertaking activity,

F_i = average frequency of use of appliance, or activity,

V_i = the volume of water consumed by appliance, or activity,

mu = miscellaneous use in litres/head/day

This calculation forms the basis for projecting both unmeasured and measured pcc. To complete the household forecast, the pcc values are multiplied by the respective unmeasured and measured populations to generate total household demand.

This forecast process is summarised in four key stages (Figure 4.2):

- generation of unmeasured pcc;
- generation of measured pcc;
- generation of unmeasured and measured population;
- calculation of total household water demand.

Each stage represents a two step process requiring the derivation of base-year data and forecast assumptions.

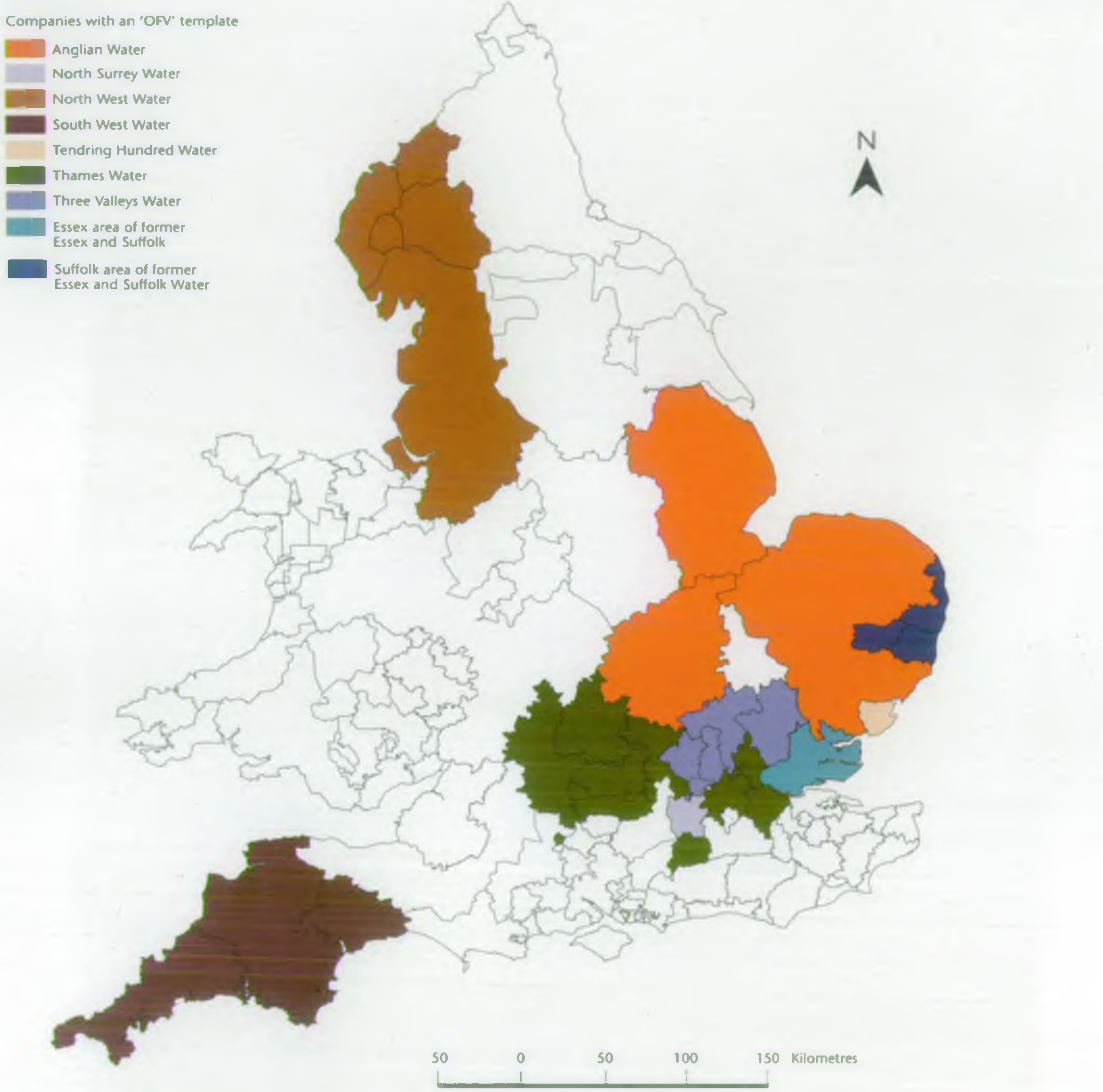
4.2 Generation of unmeasured per capita consumption

4.2.1 Base-year unmeasured per capita consumption

The micro-component based approach to forecasting is accepted as water industry "best practice" (UKWIR/NRA, 1995; UKWIR/Environment Agency, 1997). In their water resources plans many water companies adopted such an approach. Several provided supporting documentation and justified their breakdown of base-year unmeasured pcc into micro-components. This was not a specific requirement of the Water Resources Planning Guideline (Environment Agency, 1997a), so not all companies provided this level of information.

Twelve water companies report using a micro-component approach in their water resources plans. Water companies have used a number of different sources of micro-component data in the base-year, including the results from their own consumption monitors. A number of companies used the results from the monitors of another company, with adjustments to reflect different socio-economic regional characteristics.

Figure 4.3 **Water companies' micro-component data used**

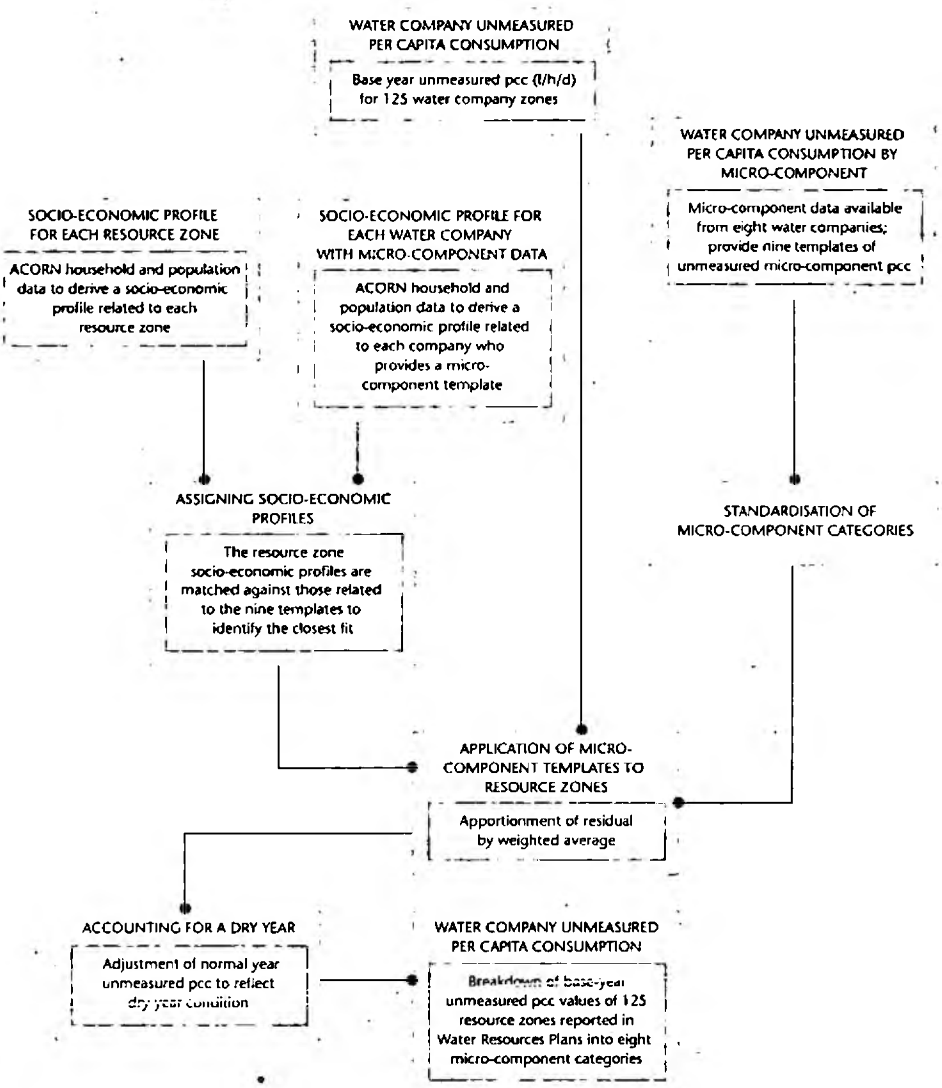


At the time of our analysis, micro-component data were available from eight water companies in England and Wales. Of these, only one provided information to reflect regional variation within the company. This gave us nine sets of micro-component data:

- Anglian Water;
- Essex and Suffolk Water – Essex zone;
- Essex and Suffolk Water – Suffolk zone;
- North Surrey Water;
- North West Water;
- South West Water;
- Tendring Hundred Water;
- Thames Water;
- Three Valleys Water.

These companies collectively supply about 47 percent of the household population in England and Wales, distributed across the country and including both water only and water and sewerage companies (Figure 4.3). These eight companies supply a cross-section of customers from different social groups, in rural and urban communities, with varying levels of affluence.

Figure 4.4 Process for breaking down unmeasured per capita consumption into micro-component categories



With nine different sets of micro-component data to work with, we faced a challenge. In using the base-year unmeasured pcc values from the water resources plans, our objective was to develop a nationally consistent micro-component data set for each of the 125 resource zones of England and Wales. To meet this objective we developed an approach to link those companies for which we had micro-component data with the remaining zones. This entails using the nine sets of micro-component data as templates, which we applied across the 125 resource zones. To achieve this we had to consider three issues:

- standardisation of micro-components;
- assignment of micro-component templates to the 125 resource zones;
- account for a "dry year" demand condition.

Figure 4.4 summarises this process.

Standardisation of micro-components

Our analysis of the nine sets of micro-component data revealed a number of inconsistencies related to the use of micro-components. Not only did the micro-components vary between the water companies, but they were also different from the standard set we had defined for our forecasting purposes (Table 4.1). For example, some companies explicitly included a component for drinking and cooking, whereas others did not. Clearly, water will have been used for this purpose even if no volume was assigned to the category. Such issues had to be addressed in a consistent manner in order to produce a comparable set of micro-components. To achieve this, company-specific micro-components and related OFV values were assessed against our standardised set (Table 4.1). Micro-component categories that were directly comparable remain unchanged.

Table 4.2 Range of micro-component per capita consumption values across the eight template companies

Household water use components	Micro-components	Range of template unmeasured pcc (litres/head/day)
Toilet use	WC	35.5 - 45.0
Personal washing	Bath Shower Power shower Hand basin	21.2 - 35.3 4.5 - 10.6 1.7 - 9.3 10.0 - 15.0
Clothes washing	Washing machine Clothes washing by hand	13.8 - 24.6 0.6 - 1.3
Dish washing	Dish washer Dish washing by hand	1.3 - 5.3 7.6 - 10.0
Car washing	Car washing	0.9 - 1.2
Garden watering	Sprinkler Other garden watering	0.3 - 4.2 3.6 - 9.7
Direct heating systems	Combination boiler	0.1
Miscellaneous	Miscellaneous	15.0 - 33.9

This process generated nine micro-component templates in line with the standardised set, which allowed direct comparison between the nine sets of data. Table 4.2 shows the ranges of micro-component pcc. The differences between the templates reflect the relative affluence and socio-economic profile of customers in the water company or resource zone, as well as regional climate.

Assignment of micro-component templates

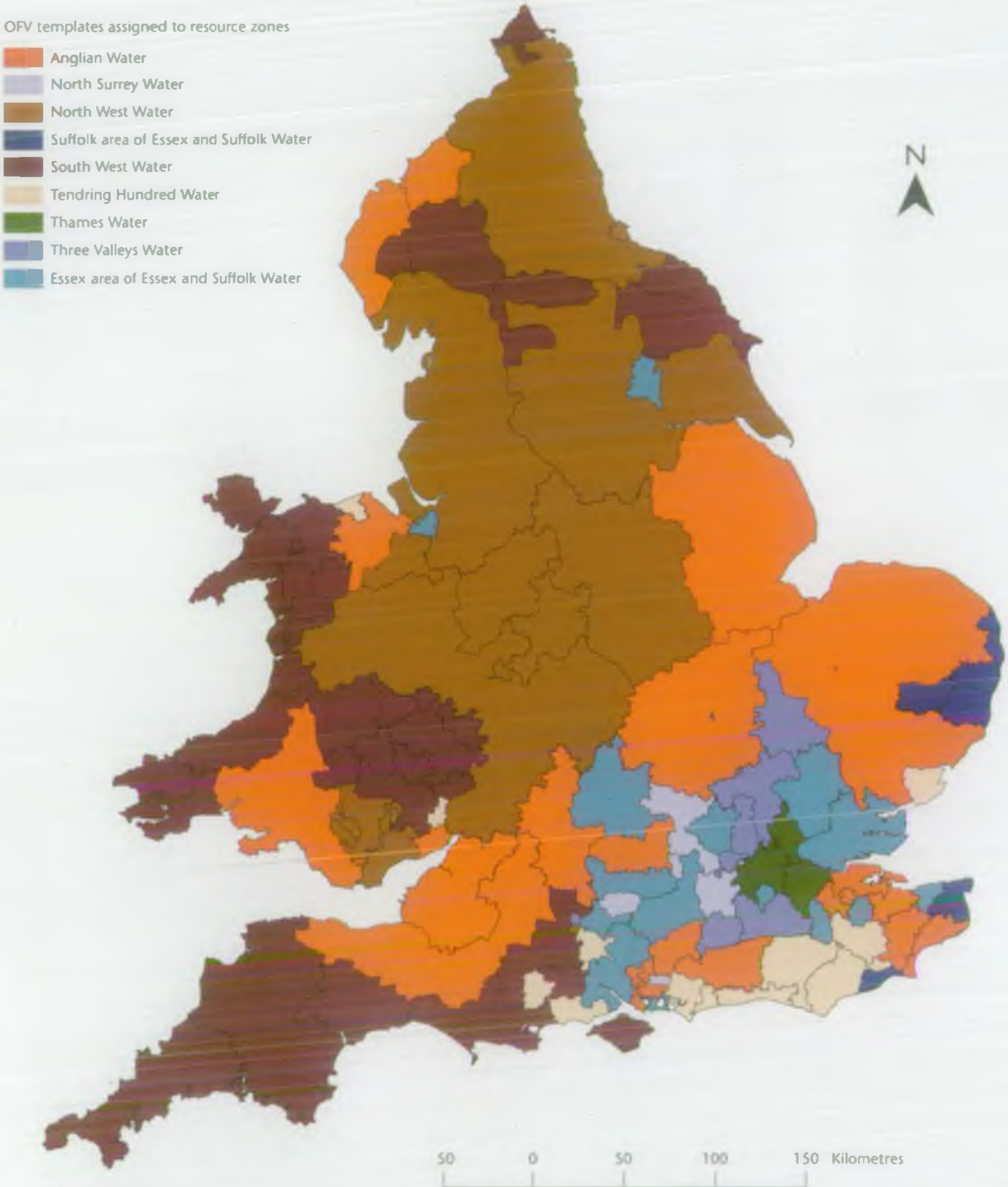
Having developed a consistent set of micro-component templates, we devised a process to assign the 125 resource zones to one of the nine templates. Our approach assumes that there is a link between socio-economic status and water use (Consumers Association, 1996; Cuninghame *et al* 1996; DoE/Ofwat, 1992; UKWIR/Environment Agency, 1997; ONS, 1996; Williamson *et al*, 1996), particularly in relation to ownership of household appliances such as washing machines and dishwashers.

In the absence of any classification system that explicitly addresses the relationship between socio-economic status and water use, we have used "A Classification Of Residential Neighbourhoods" (ACORN) system developed by CACI Ltd. This approach draws on 79 different data items from the 1991 Census. These are combined to produce a socio-economic classification system of 54 Types, 17 Groups and six Categories. This was applied to household and population data to provide an indication of socio-economic status and lifestyle. We used these data for each resource zone in England and Wales, to provide a breakdown of the proportion of households within each ACORN Type and Group. The distribution of households across the 17 ACORN Groups provides an indication of the profile of socio-economic status and therefore the implied lifestyle characteristics related to each resource zone. The same process has been applied to generate company-wide socio-economic profiles related to the eight companies that make up the micro-component templates.

The socio-economic profiles of each resource zone are matched against those related to the nine micro-component templates. We selected the best fit between the profile of each resource zone and that of one of the nine templates, and on this basis assigned each resource zone to one of the templates. The results of this assignment process are set out in Figure 4.5, and reflect differences between rural and urban areas as well as regionalisation. Not unexpectedly, water companies in the south east are matched with micro-component templates originating from a similar area; Wales is largely matched with the south west, while the Midlands and north of England match against the north west.

The micro-component templates provide a breakdown of household water use. Not unexpectedly, the OFV values related to each micro-component vary across the nine templates (Table 4.2). The variation is due in part to the use of information from specific water company consumption monitors and variations in the method of estimation. The results also reflect differences in socio-economic mix. For example, households headed by a semi-skilled or unskilled manual worker are much less likely to own a dishwasher than those headed by professionals (ONS, 1996).

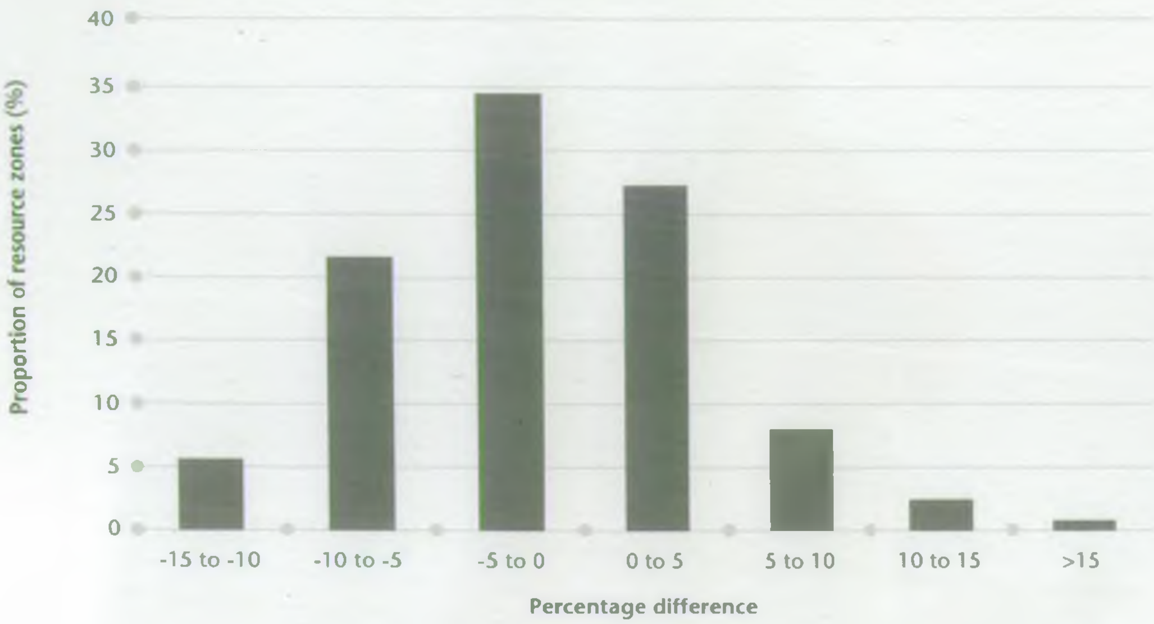
Figure 4.5 **Assignment of resource zones to micro-component template companies**



The garden watering micro-component is the exception; although socio-economic differences are important, variation in regional climate plays a greater role in determining the frequency and duration of each garden watering "event". On this basis it would not be appropriate to assign a micro-component template for a dry zone in the south east to a wetter zone in the north or west. Hence we stripped out the garden watering micro-component from the nine templates and replaced them with our own assessment (Appendix 2). For those water companies with information, comparison of the two sets of garden watering micro-components are broadly similar. However, comparison of our resource zone values indicates that there is more variation; our figures range between 3 and 14 l/h/d compared to 5 and 12 l/h/d for the water company estimates. There was least similarity between the estimates where reported garden use was low. Surprisingly, the lowest reported garden use micro-components coincided with resource zones in the south east of England.

At the end of this process, each resource zone had two sets of unmeasured pcc values – one derived from the micro-component template, the other reported by the

Figure 4.6 Extent of micro-component template adjustment required to match resource zone unmeasured per capita consumption from water company plan



water companies in their water resources plans. Analysis of the difference between these two sets of values reveals that for more than 90 percent of resource zones the residual value is within a range of +/- 10 percent. The "outliers" are generally those resource zones with a small population or unique socio-economic profile (Figure 4.6).

The residual difference had to be reconciled. To achieve this we reapportioned the value using a weighted average. The proportionate breakdown of micro-component categories from each template provides an indication of the relative size of each micro-component. Starting with the largest micro-component, the residual is reapportioned using the relevant micro-component's percentage value. For example, if bathing represents 10 percent of pcc within the micro-component template, then 10 percent of the residual difference is assigned to this micro-component. This generated a consistent set of micro-component values for the 125 resource zones related to average demand in a normal year.

Accounting for a dry year

The water resources strategies plan the sustainable management of water resources on the basis of a dry year. To reflect this in our household demand forecasts, our micro-component data were adjusted to represent average demand in a dry year. Using information from the water resources plans for each resource zone, we compared normal and dry year unmeasured pcc values. The difference between these two values represents the additional demand due to dry weather conditions. In line with Herrington (1996), we have assumed that this increased demand is attributable to:

- the increased frequency of garden watering;
- the increased frequency of personal washing.

The difference between the normal and dry year unmeasured pcc values has been reapportioned to these two micro-components. Drawing on Herrington (1996), two assumptions underpin this process:

- in a dry year the garden watering season may extend from four months (May-August), to six months (April -September); this increases the annual average frequency of sprinkler use from 0.023 to 0.034 /head/day, and other garden watering from 0.045 to 0.067 /head/day;
- the annual average frequency of showering increases from 0.87 /head/day in a normal year to 0.97 /head/day in a dry year.

On average, this equates to a normal year pcc value of 12.15 litres/head/day compared to a dry year value of 16.18 litres/head/day; a difference of 4.03 litres/head/day. Of this, 83 percent relates to the garden watering micro-component category, while 17 percent relates to personal washing.

This completed the final step in the process, with the dry year unmeasured pcc values of the water resources plans broken down into a consistent set of micro-components for the 125 resource zones of England and Wales.

Table 4.3 **Link between the micro-components and key drivers of household demand**

Component	Toilets			Personal washing												Clothes washing						Dish washing						Car washing			Garden watering						Direct heating systems		
Micro-component	Toilets			Bath			Shower			Power shower			Hand basin			Washing machine			Clothes washing by hand			Dish-washer			Dish washing by hand			Car washing			Sprinkler			Other garden watering			Combi-boiler		
	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V	O	F	V
Water regulations			✓			✓						✓						✓						✓															
Techological change			✓						✓			✓						✓						✓									✓						✓
Behavioural and lifestyle change				✓	✓		✓	✓	✓	✓	✓	✓			✓		✓			✓			✓			✓			✓		✓	✓			✓		✓		
Affluence	✓						✓			✓						✓		✓		✓		✓		✓		✓		✓			✓						✓		

Key: O = Ownership F = Frequency V = Volume

4.2.2 Forecast unmeasured per capita consumption

Table 3.3 reports our assessment of the effects of the four scenarios on the key drivers of household demand. This provides the framework for the development, by scenario, of specific assumptions related to the ownership, frequency and volume per use of each micro-component. Table 4.3 shows the link between each of these elements of micro-component use and the drivers of household demand. Not unexpectedly, the volume element proves particularly sensitive to water policy drivers such as regulations and technological innovation. There is of course a link between these two drivers, as changes in regulation may act as a catalyst for technological innovation and vice versa. Individual behaviour and lifestyle will influence the frequency element of several of the micro-components. The number of times an individual bathes or showers in a week, the length of time spent in the shower, or the propensity to water the lawn will be influenced by the individual's values, relative affluence and lifestyle. The ownership of water-using equipment and sanitary ware will be driven in large part by affluence and the individual's willingness or need to invest in replacement items.

Our scenario-specific assumptions and growth factors are set out in Appendix 3. In this section we focus on the principles underpinning the development of assumptions related to four categories of household demand: toilets, personal washing, clothes washing and dish washing.

Toilets

To assess the impact of the four scenarios on the toilet micro-component we have considered six different types of toilet. Each of these has different cistern volumes and levels of ownership. We have assumed that the frequency of toilet flushing will not vary by scenario.

All households are assumed to include at least one toilet. The different types of cistern volumes that currently exist within the housing stock in part reflect the effects of the 1970 and 1993 Water Byelaws. The recent Water Supply (Water Fittings) Regulations, specify that all new single-flush toilets are limited to a maximum flush volume of 6 litres; dual-flush toilets are set at a maximum of two-thirds of the single-flush volume. Consultation with the Bathroom Manufacturers Association (formerly the British Bathroom Council) suggests that households currently replace sanitary ware once every 20 years. We have assumed this represents an upper limit on the rate of cistern replacement as it is based upon projected total sales and not specifically on the rate of domestic installation, new or replacement. The replacement rate in domestic properties is likely to be less than this. These values are very different from those reported in Herrington (1996), and suggest that this remains an area of uncertainty.

We have assumed in Scenarios Alpha and Beta that cistern volumes do not differ from those currently available. Within Scenario Gamma, the implementation of stricter regulation on cistern volumes coupled with the emphasis on efficient technology results in the introduction from 2015 of a 4 litre single-flush cistern volume. Scenario Delta also considers a low volume dual-flush cistern, with this technological innovation driven by the high priority placed on the environment.

Figure 4.7 Ownership of toilet types, by scenario in 2025

In line with field trial evidence from Caroma International in Australia we have assumed that from 2015 a 4 litre/2 litre cistern volume will be available as well as the 4 litre single-flush. This gives a combined average flush volume of 3.3 litres (White, 1999, 2001).

Ownership of these different types of toilet reflects our assumptions regarding the rate at which households replace existing sanitary ware. In Scenarios Alpha and Delta we have assumed a replacement rate of one in 40 years, on the basis that the low levels of affluence in both scenarios will inhibit investment. The high level of personal affluence in Scenario Beta means that we have assumed a replacement rate of one in 30 years. In Scenario Gamma, we have assumed a replacement rate of one in 20 years on the basis of the relatively high levels of personal affluence combined with individuals' willingness to invest in new technologies with improved environmental performance. The influence, by 2025, of these differential replacement rates on the ownership levels of the different toilet types is demonstrated in Figure 4.7.

Although we have assumed that the frequency of toilet flushing will not vary by scenario, we have considered the influence of substituting mains water with alternative sources such as greywater. We have considered the effects of greywater recycling in Scenarios Gamma and Delta by reducing the frequency of toilet flushing using mains supply. We have assumed that from 2010 technological innovation will improve the reliability of greywater systems and enable their production and installation at low cost. In Scenarios Gamma and Delta we have assumed that 10 percent of households will own a greywater system by 2025.

Table 4.4 shows the combined effect of these changes on average cistern flush volumes.

Table 4.4 Average cistern flush volume, by scenario

Scenario	1997/98	2024/25
Scenario Alpha	8.4 litres	6.6 litres
Scenario Beta	8.4 litres	6.1 litres
Scenario Gamma	8.4 litres	4.8 litres
Scenario Delta	8.4 litres	5.5 litres

Personal washing

To explore the influence of the four scenarios on personal washing we have considered the interdependencies of four micro-components: bath, standard shower, power shower and hand basin use. These micro-components are particularly sensitive to individual preferences, reflected in the frequency of taking a bath or shower, the duration of a shower or the volume of water in a bath. We have distinguished between a standard shower and power shower based on flow rate. A survey of shower manufacturers reports that power shower flow rates range between 12 and 20 litres/minute (BRE, 2000a and b). Assuming an average shower duration of 10 minutes this results in a maximum power shower volume of 150 litres/event.

Over the period 1976 to 1990 there has been a general trend towards increased personal washing, reflecting the rapid growth in ownership of showers (Herrington, 1996). Across all scenarios, we have assumed that this trend continues. However, we have included a ceiling of 0.9/head/day on average frequency of daily bathing or showering "events" to be consistent with evidence of bath and shower frequency from Herrington, 1996. Within each scenario, the composition of this frequency value will vary, reflecting for example the switch from power to standard showers.

The greatest variation between scenarios relates to the ownership and volume associated with power showers. In Scenarios Alpha and Beta we assume a maximum volume of 150 litres/event by 2025, whereas in Scenario Gamma showers are subject to strict flow rate regulation. Hence in Scenario Gamma regulations limit showers that use more than 6 litres/minute, effectively eliminating current types of power shower from the market. In Scenario Gamma we assume that technological innovation will result in a shower that combines a low flow rate with the "sensation" of a power shower.

The ownership of power showers varies considerably between the scenarios, reflecting the relative affluence of the population and their willingness to replace existing appliances. Given the high levels of personal affluence in Scenario Beta we have assumed that 59 percent of households will own a power shower by 2025. Within Scenario Gamma, the introduction of strict regulations on maximum flow rates, combined with the high levels of personal affluence, means that the trend to power showers is reversed from 2010. Individuals are willing to replace power showers with standard units and hence we assume from 2010 a rate of replacement of one in 20 years. In Scenario Delta, the emphasis on individual environmental responsibility means that power showers are stigmatised as a highly inefficient use of water. To minimise their personal environmental impact, individuals replace their power showers at a rate of one in 15 years. By 2025, the use of power showers effectively disappears in this scenario. Figure 4.8 illustrates the cumulative effects of these assumptions.

Clothes and dish washing

White goods are particularly sensitive to technological innovation and the development of more water-efficient appliances. The level of uptake of these appliances will reflect the level of personal affluence and willingness to invest in water-efficient goods.

Washing machines on the market today use between 40 and 100 litres of water or more per cycle (DETR, 1999b). Evidence from the general household survey indicates that in 1996, 90 percent of households owned a washing machine (Herrington, 1996); by 2010 DETR (1999b) forecasts that this figure will be 94 percent. Ownership of dishwashers is significantly lower, accounting for 20 percent of households in 1996 (Herrington, 1996). Ownership of these appliances varies in relation to personal affluence.

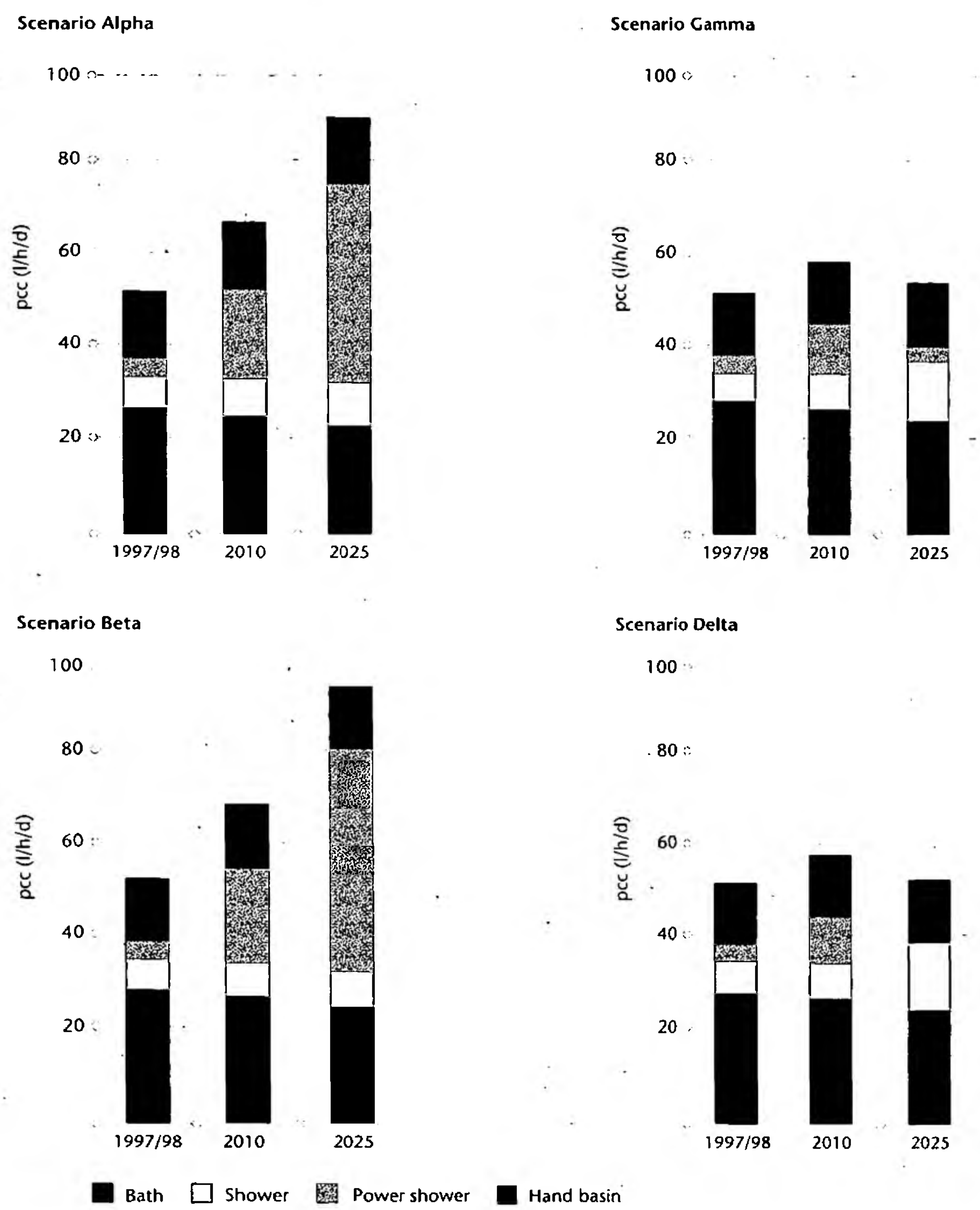
In all except Scenario Delta, we have assumed that the level of washing machine ownership will reach 94 percent in 2010 and then remain constant across the forecast period. In Scenario Delta the level of ownership will decline by 4 percent between 2015 and 2025, to reflect the emergence of communal laundry enterprises. In line with Herrington (1996) we have applied a reduction in the frequency of washing machine use in Scenarios Alpha, Beta and Gamma to reflect the decline in household occupancy. In Scenario Delta, the frequency level is maintained as at 2015 to reflect the stabilisation in household occupancy. Technological innovation drives the reduction in volume per use in Scenarios Beta (50 litres), Gamma and Delta (both 40 litres); Scenario Alpha reaches 80 litres by 2010 and then remains constant.

Dishwashers on the market today use between 12 and 40 litres per cycle (DETR, 1999b). Our assumptions relating to ownership of dishwashers are in line with trends reported in Herrington (1996). This reports a general increase in ownership of 1.7 percent per year between 1991 and 1997. In Scenario Alpha we maintain this rate of growth until 2010 and thereafter it declines to 1.5 percent per year. To reflect the higher level of affluence in Scenario Beta, we have increased the growth rate to 2 percent per year. Scenario Gamma assumes a rate of 1.7 percent per year across the planning period, and similarly for Scenario Delta until 2010; thereafter the rate declines to 1 percent per year to reflect the lower rate of affluence. The frequency of dishwasher use is maintained at the base-year values across the planning period for all scenarios. Once again technological innovation drives the reduction in volume per use in Scenarios Beta (20 litres), Gamma and Delta (both 15 litres); Scenario Alpha reaches 30 litres by 2010 and thereafter remains constant. Figure 4.9 illustrates the cumulative effects of these assumptions.

4.2.3 Total unmeasured per capita consumption

Figure 4.10 shows the cumulative effect of these scenario-specific assumptions on all the micro-components of unmeasured pcc. The largest increase is in Scenario Alpha, where unmeasured pcc increases by 25 percent on average.

Figure 4.8 Unmeasured per capita consumption personal washing micro-component, by scenario in 2025



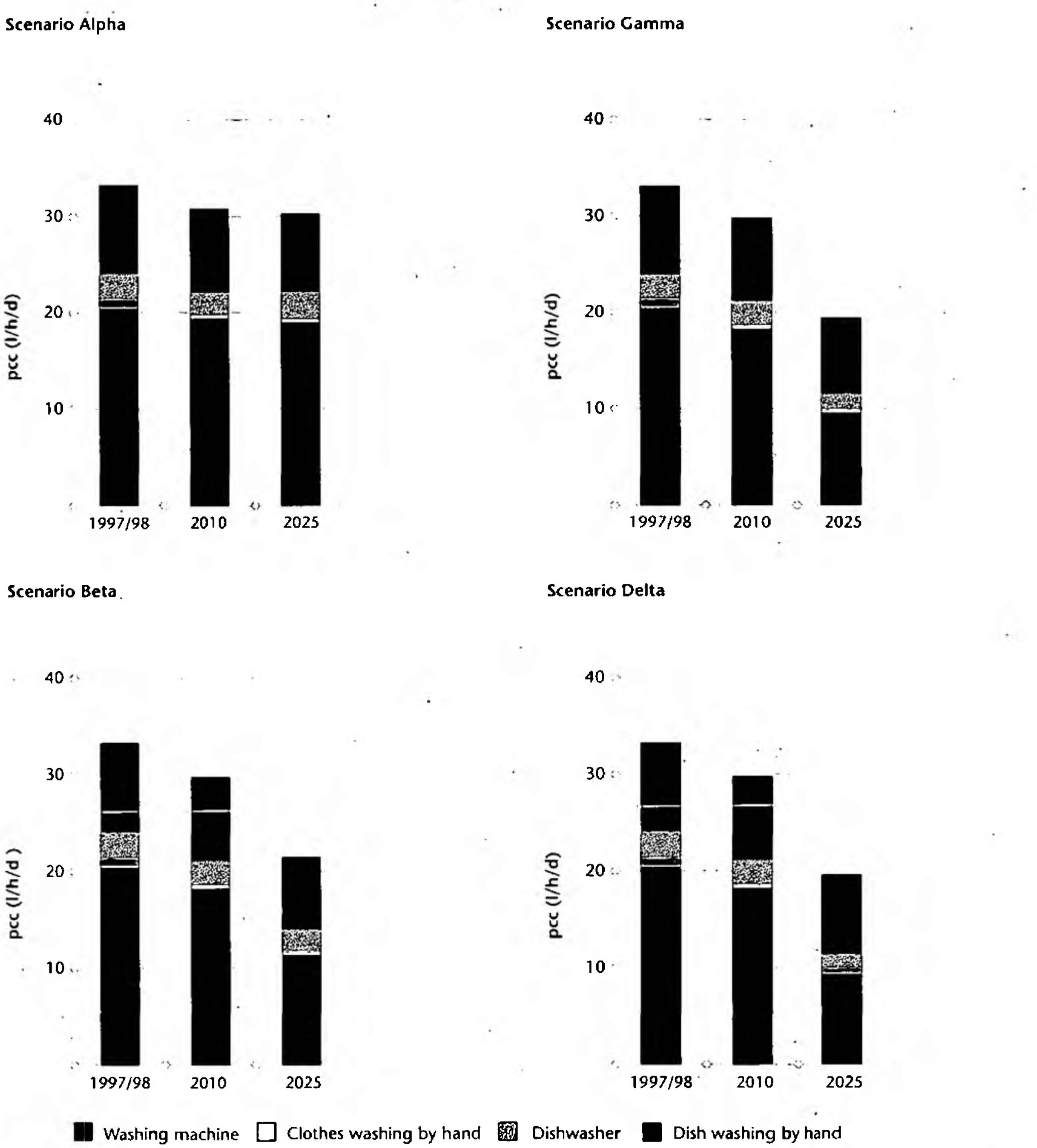
4.3

Generation of measured per capita consumption

4.3.1 A micro-component approach to demand suppression

In developing assumptions to account for the effect of metering on demand, we have applied an approach in line with the recommendations of the UKWIR/Environment Agency (1997) publication *Forecasting Water Demand Components: Best Practice Manual*. Rather than simply apply a single suppression factor to unmeasured per capita consumption, it was necessary to consider the effect of metering on each micro-component of household demand. Limited information is currently available on the effect of metering on the pattern of use of each appliance. In the

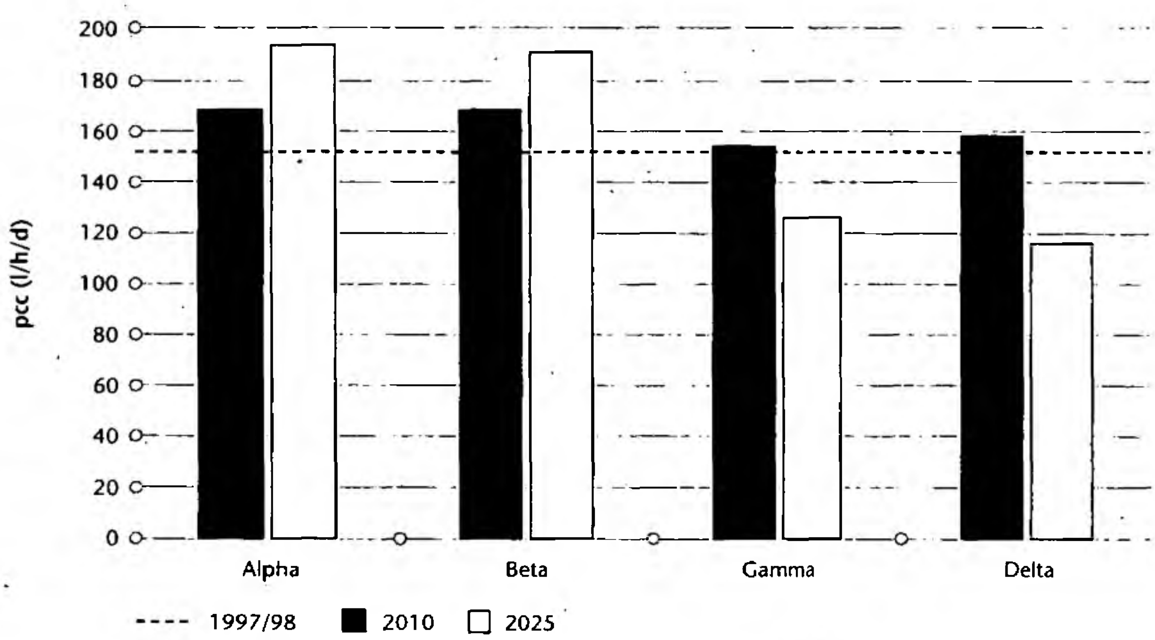
Figure 4.9 Unmeasured per capita consumption clothes and dish washing micro-component, by scenario in 2025



context of the four scenarios switching to a metered supply will have both a short-term and long-term effect on water use behaviour. Over the short term, the influence of metering will be evident as a shift in the frequency and duration of use related to some micro-components. For example, the number of times the garden is watered or length of time spent in the shower may change. However over time this will change as the profile of metered households changes. Over the longer term, metering with appropriate tariffs will change attitudes towards water use. When new appliances are purchased, people will choose those that are water-efficient. This distinction underpins our development of scenario-specific assumptions.

We have taken as our starting point the metering suppression values reported in the National Metering Trials Working Group (1993), Edwards (1996) and Pezzey and Mill (1998). These reported values have

Figure 4.10 National average unmeasured per capita consumption, by scenario in 2010 and 2025



been broken down into suppression factors related to each micro-component. For each we have assessed the extent to which metering is an effective stimulus for behavioural change. Usage relates to either a fixed volume, for example toilet use, or is time related as with showering. We have assumed that the greatest potential for reduction relates to micro-components where usage is time related: principally personal washing and garden watering.

For personal washing, we have assumed that switching to a metered supply will result, over time, in an increase in showering frequency at the expense of baths. For garden watering we have assumed that metering will result in people watering their garden less frequently and using a sprinkler less often.

For each scenario, we have adjusted the suppression factors to reflect the scenario-specific approach towards metering and regulation as well as the degree to which individuals are willing to change their behaviour to minimise their impact on the environment.

The resulting suppression factors are reported in Table 4.5. Although the suppression factors have been applied uniformly to the micro-components for each resource zone in England and Wales, the effect varies in relation to the initial size of each micro-component (Table 4.6).

4.3.2 Total measured per capita consumption

Figure 4.11 illustrates the cumulative effect of both the scenario-specific assumptions and the suppression factors on measured pcc.

4.4 Generation of unmeasured and measured population

A census is undertaken once every 10 years and provides the most accurate assessment of UK population at a specific time. Government uses census information to produce population forecasts every five years. These forecasts are updated annually to reflect actual trends in births, deaths and migration. In contrast, forecasts of household numbers are not produced as a matter of routine with the Government, National Assembly for Wales (NAW), government office regions and local authorities producing estimates on an intermittent basis. A range of growth rates is reported for household numbers (DETR, 1999a, ONS, 1999, water company water resources plans incorporating sub-national projections). Latest government projections suggest an increase of 3.3 million households in England and Wales between 1996 and 2016. This is largely due to the trend towards smaller household size (DETR, 1999a, NAW, 1999).

Forecasts of population and household numbers are an integral element of the water company water resources plans. In developing these, water companies consulted

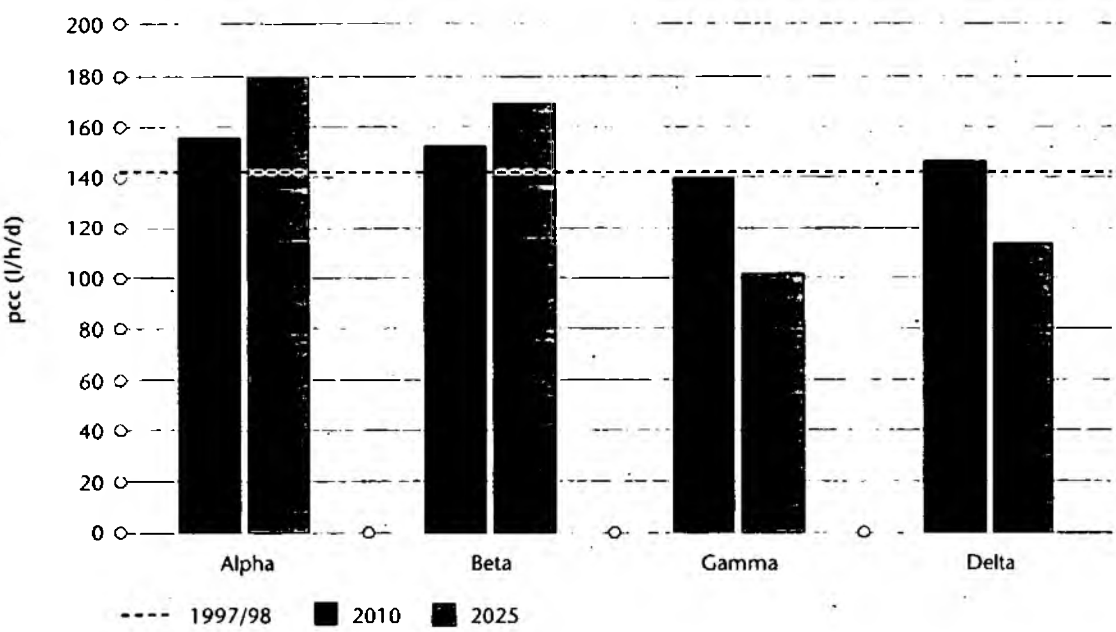
Table 4.5 Demand suppression factors

Micro-component	1997/98	2025			
	All scenarios	Alpha	Beta	Gamma	Delta
WC	1.00	1.00	1.00	1.00	1.00
Personal washing	0.80	0.80	0.80	0.65	0.97
Clothes washing	0.95	0.95	0.95	0.99	0.99
Dish washing	0.95	0.95	0.95	0.99	0.99
Garden watering	0.90	0.90	0.90	0.7	0.97
Car washing	0.90	0.90	0.90	0.8	0.98
Direct heating systems	1.00	1.00	1.00	1.00	1.00
Miscellaneous	0.93	0.93	0.93	0.88	0.99

Table 4.6 The proportionate difference in measured and unmeasured per capita consumption at national and regional level

	National	Anglian Region	Midlands Region	North East Region	North West Region	South West Region	Southern Region	Thames Region	Environment Agency Wales
Scenario Alpha	7.39%	10.87%	11.31%	12.08%	11.13%	9.40%	11.09%	8.73%	11.08%
Scenario Beta	11.42%	10.76%	11.92%	11.73%	11.85%	11.40%	11.43%	10.89%	12.21%
Scenario Gamma	19.08%	19.25%	18.95%	18.55%	18.92%	19.63%	19.39%	19.22%	18.55%
Scenario Delta	2.09%	1.51%	0.92%	2.79%	1.41%	1.83%	0.46%	2.27%	1.09%
National Metering Trials (1993)	Average suppression 11%								
Pezzey and Mill (1998)	Average suppression 14.1% - 25.7%								
Edwards (1996)	Average suppression 15%								

Figure 4.11 National average measured per capita consumption, by scenario in 2010 and 2025



with local authorities, DETR, CACI, ONS and regional government offices to establish robust estimates of growth in household numbers within resource zones. Comparing the national sum of households from the water resources plans against latest government projections (DETR, 1999), the figures reported by water companies are 2 percent or 0.5 million lower than government projections throughout the forecast period. Three factors may explain this relatively small difference:

- not all households receive a public water supply;
- there are different interpretations of what constitutes a household;
- water companies draw on information from a combination of sources, for example national projections and local plans.

Given that water companies are not all drawing on the same sources of population and household data, we have used data supplied by CACI to ensure that we have a consistent source of this data. Enumeration district information was used to produce resource zone population numbers based upon the 1996 population projection (building on the 1991 census information), and adjusted to incorporate the 1997 mid-year estimate. For England and Wales, the total population was 2 percent higher than the sum of populations reported in the water resources plans. Since estimates of household numbers are related to the population estimates it is not surprising to find a similar difference between water resources plans and totals for England and Wales.

Since unmeasured pcc estimates are calculated from household consumption monitors, the average unmeasured pcc should be representative, yet independent, of the total population. Differences in population would, however, affect the pcc if unmeasured pcc was derived crudely from total unmeasured consumption (unmeasured water delivered less supply pipe leakage) divided by unmeasured population. The latter approach does not conform with industry "best practice". Thus, the small difference in reported total population between CACI and water resources plans will have little impact when analysing incremental demand.

4.4.1 Household and population numbers – base-year and forecast

The split between measured and unmeasured population will vary in relation to each scenario, reflecting our assumptions about household metering. We established a relative split between unmeasured and measured households to generate the respective populations by applying occupancy rate assumptions.

Household metering assumptions

The Foresight framework makes specific reference to metering, indicating the proportion of households that would be metered in some scenarios (DTI, 1999). This provides the framework for our assumptions, summarised in Table 4.7.

Recent trends in the rate of meter uptake were taken from the water company annual returns to Ofwat as well as information from their water resources plans. In line with Ofwat's final price determinations, we have assumed a conservative growth in the number of metered households. For most companies, this represents an additional 10 per cent on 1997/98 levels. This growth assumption has been applied across all scenarios until 2005; thereafter the scenario-specific assumptions start to take effect.

The water companies' forecasts of meter penetration have been used from 2005 to 2010 to reflect the potential for increased rates of uptake when combined with positive promotion. The only exception to this is in Scenario Alpha, where from 2005 metering programmes are curtailed. Although existing metered properties continue to pay for supplies, this option is not available to other householders except those in the south and east (Figure 4.12). This represents a scenario with public resistance to metering. Lack of investment in new resource and infrastructure maintenance means that some water companies in the south-east must meter in order to balance supply and demand.

Proportions of unmeasured and measured population

Household occupancy rates vary in relation to the level of metering; in the early phases of a metering programme, the financial incentives tend to encourage those with a lower occupancy to switch. A lower occupancy level is therefore often reported for metered households (UKWIR/Environment Agency, 1997). Over time, as more households switch, the measured occupancy rate increases. Conversely, the number of unmeasured households decreases and the unmeasured occupancy rate may then rise sharply towards the end of the planning period. This is in line with trends reported in the water resources plans submissions. Over time, such differences will influence the proportions of unmeasured and measured population supplied.

The CACI population figures were broken down into unmeasured and measured proportions using

Table 4.7 **Metering assumptions for each scenario**

Scenario	2004/05	2009/10	2014/15	2019/20	2024/25
Alpha	Likely water company rates following Ofwat final price determination	Continue with rate of metering allowed by Ofwat in 2005 for those companies in the south and east. Elsewhere metering is curtailed so no additional households switch to a metered supply			
Beta		Water company rates	Metering to a maximum of 95% of all properties by 2015		
Gamma		Water company rates	Metering to a maximum of 95% of all properties by 2020		
Delta		Water company rates			

occupancy rate information reported in the water resources plans. Reported occupancy rates were used to derive a measured occupancy rate. We applied this value to the CACI data to generate a measured population figure. This was then subtracted from the total population figure to give the unmeasured population. This process was completed for each scenario. The results of this process are illustrated in Figure 4.13, where total population is broken down into unmeasured and measured portions.

4.5

Generation of total household water demand

Total household demand was calculated from the product of the unmeasured and measured per capita consumption and the respective populations (Figure 4.13).

4.5.1 Climate change

Climate change will affect the demand for water in many different ways. Our understanding of the relationship between weather and water use is still developing, so it is not possible to be certain about how climate change will affect demand. DETR has commissioned a study from the Environmental Change Institute at Oxford University to investigate the impact of climate change on domestic, industrial and agricultural water use. This will report in 2002, and we will review our work in the light of this.

In assessing the effects of climate change on household demand, we have used the best information available at present. The definitive study, carried out by Herrington (1996), suggested that additional demand for water would be predominantly driven by temperature. Herrington identified three components of household use that would be affected by an increase in temperature:

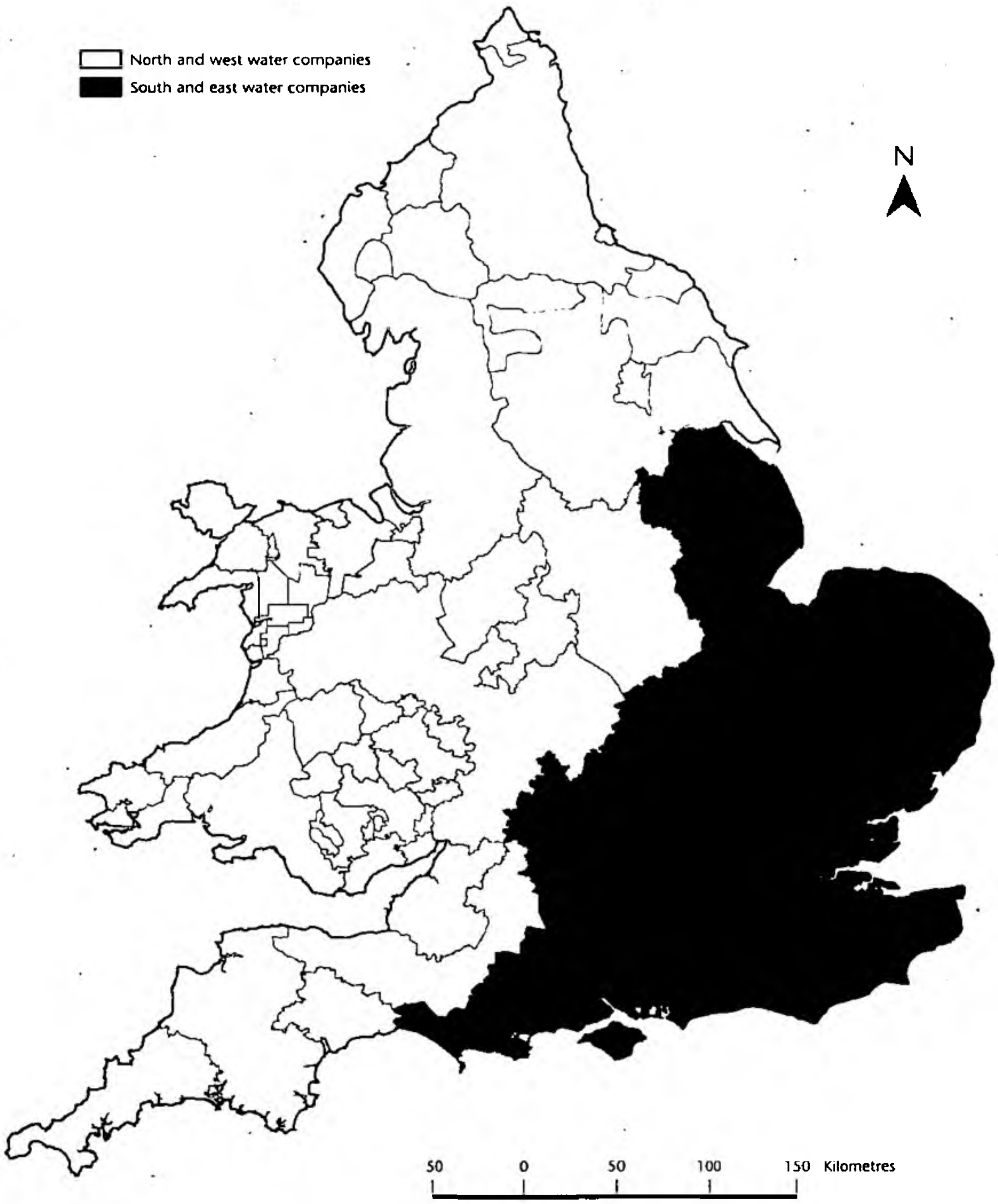
- personal showering;
- lawn sprinkling;
- other garden use.

We used Scenario Beta to consider the effects of climate change on demand since shower use and garden sprinkler ownership are greatest in this scenario. As this scenario already includes a significant increase in personal washing due to changing social values, we believed there to be little scope for increased showering frequency. Therefore our analysis focused on the effects of climate change on garden watering.

In response to higher temperatures under climate change, we have assumed that there would be an increase in the frequency of each garden watering "event". Ownership of garden watering appliances does not change. The effects of climate change are likely to be greater in the south and east of England than in the rest of England and Wales (Herrington, 1996). To reflect this in our assumptions, we have divided resource zones into two groups, broadly following a line from the Wash to the South Zone of Wessex Water (Figure 4.12). For resource zones outside this area, we have reduced the effect of climate change on garden watering by a nominal amount of 33 percent. Table 4.8 summarises the effects of climate change on unmeasured demand.

From this analysis, climate change results in an increase of less than 2 percent on unmeasured and measured pcc. This translates into an increase in demand across England and Wales of approximately 180 Ml/d for 2025. This impact is distributed so that it is greater in the south and east than in the north. Under different Foresight scenarios, society would respond to climate change in different ways. It would be possible to assess this, but the quality of the data on changes in water use is poor and does not warrant such sophistication. Garden watering under Scenarios Alpha, Gamma and Delta is likely to be less common, either as a result of

Figure 4.12 | Resource zones defined as in the south and east or north and west of England and Wales



less affluent society, or because discretionary uses of water are less popular than under Scenario Beta; the impact of climate change would therefore be less than calculated for Scenario Beta.

4.6

Scenario outcomes

Figures 4.14 and 4.15 illustrates the effect of each scenario on total household demand, excluding climate change. Compared to our current position, by 2010 the changes in demand are quite small. By 2025 there are marked differences, with two scenarios seeing an increase in demand while two decrease. In each scenario the combination of factors leading to these changes are different. In this section we address each scenario in turn and summarise how the changes in social values and systems of governance affect the drivers of household demand.

Scenario Alpha: Growth in personal affluence is stifled, with limited availability and uptake of more efficient technologies. Replacement of white goods and investment in new water-using devices declines, with households preferring to repair existing appliances as necessary. Existing sanitary ware is retained.

Figure 4.13 Measured and unmeasured populations, by scenario

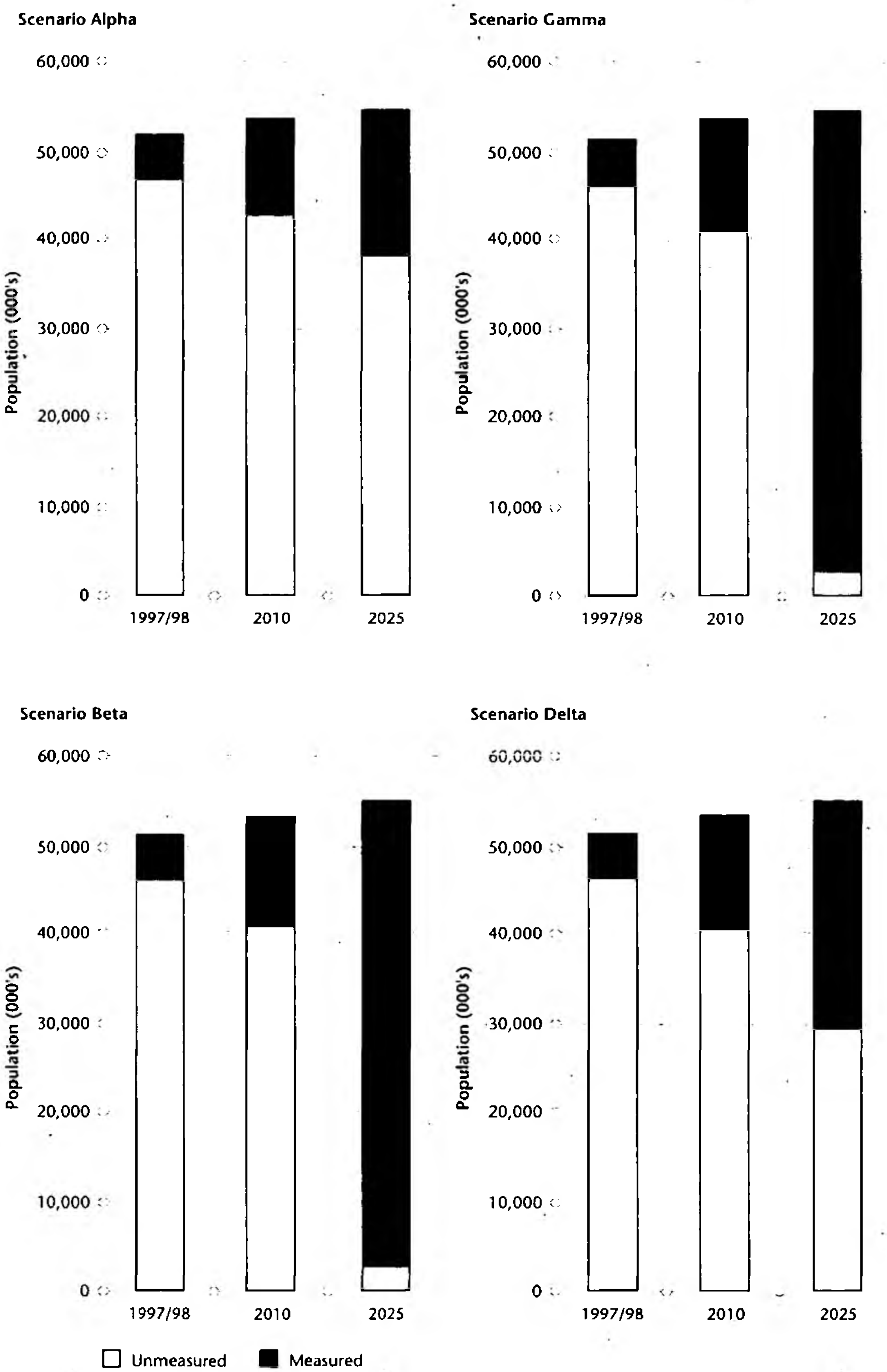


Figure 4.14 Total household water demand by micro-component, by scenario in 2010 and 2025

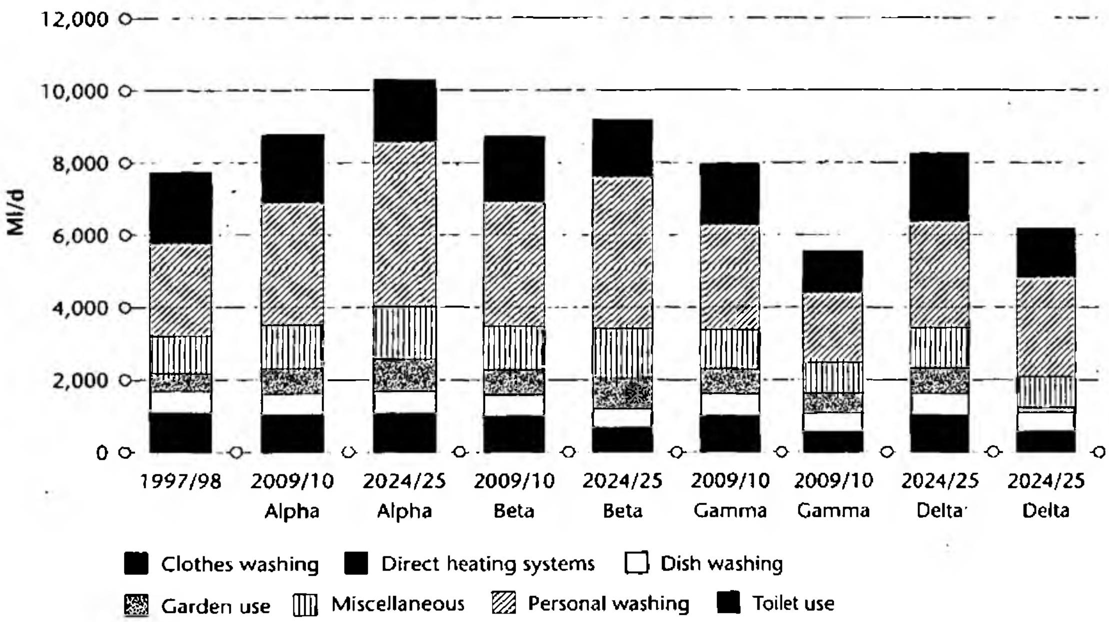


Table 4.8 Impact of climate change on household demand – Scenario Beta

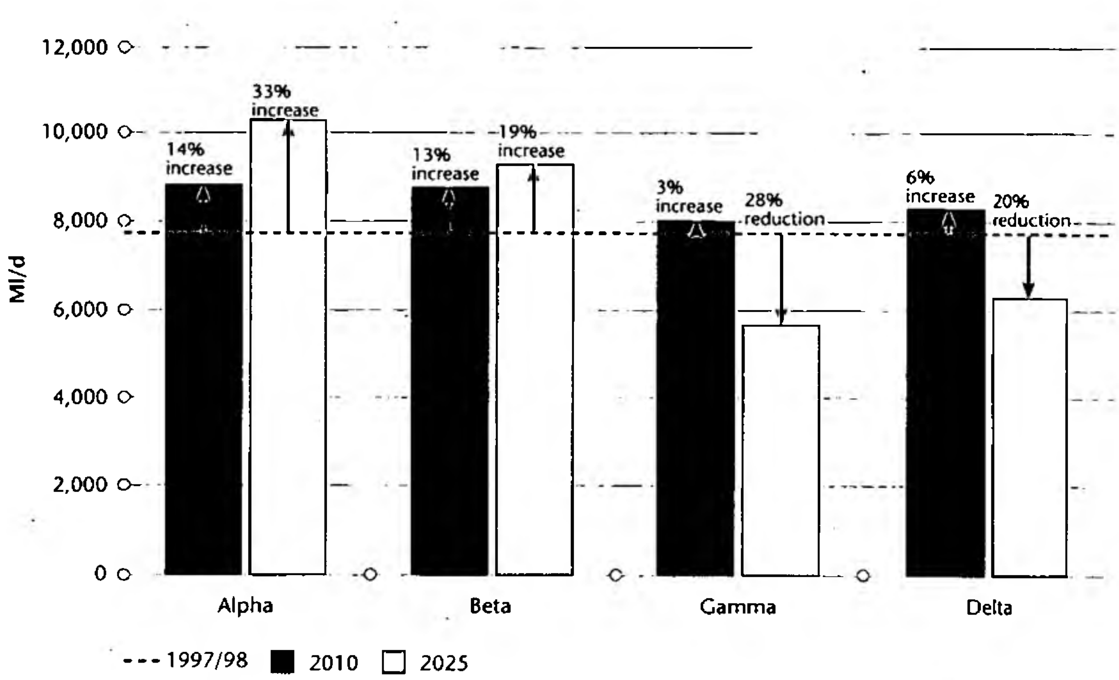
Demand component	2010	2025
Sprinkler	+1.1 l/h/d	+3.01 l/h/d
Other garden use	+0.5 l/h/d	+1.4 l/h/d

Scenario Beta: With high economic growth, technological innovation leads to improvements in the water efficiency of white goods and average washing machine use reduces to 50 litres by 2025. Discretionary uses of water increase, with more pressure washers, power showers and swimming pools.

Scenario Gamma: By 2010, measures to manage demand within existing regulations are fully implemented. From 2010 revisions to flow and volume limits in regulations provide stricter controls, particularly associated with power showers. New, highly water-efficient technology is promoted, leading to a 15-litre reduction in the volume of water used by washing machines. Given the relatively high rate of growth and affluence, the rate at which consumers replace appliances does not decline markedly. Purchases reflect their positive attitude to the environment with the uptake of more water-efficient appliances.

Scenario Delta: Consumer attitudes shift markedly, with a major impact on water-using behaviour. Overall, there is a fall in the use of water for discretionary purposes such as garden watering, which declines from 9 l/h/d to less than 3 l/h/d by 2025. There is widespread uptake of demand management measures, and a shift to low water-using appliances. Community initiatives become more widespread. Rainwater collection for garden watering is the norm where some form of watering is required.

Figure 4.15 | Total household water demand, by scenario in 2010 and 2025



5 The leakage scenarios

The formulation of the four leakage scenarios has focused in particular on the political and regulatory framework likely to influence the setting of leakage targets, and the consequent impacts for total leakage at water company level. Three scenarios reflect recent UK and overseas experience, and draw on information from the recent past to inform the development of company leakage targets. Only one scenario has necessitated detailed modelling, to reflect the impact of new technologies.

This chapter is divided into four sections: Section 5.1 sets out the background to leakage, identifying the causes of leakage rise and the range of leakage control policies. Section 5.2 describes our scenario-specific assumptions, while Section 5.3 deals exclusively with the modelling assumptions that we applied in Scenario Gamma. The final section (5.4) presents the national demand scenario outcomes in 2010 and 2025.

5.1 Leakage management context

5.1.1 Leakage and leakage control policies

All water distribution systems leak from cracks, holes and joints in the pipe network. The level of leakage is a function of the number of these leaks and bursts and the "run time" before they are repaired. These leaks and bursts are a consequence of the deterioration of the mains network, principally due to ageing but exacerbated by factors such as traffic loading, cold weather, ground movement, aggressive soils and corrosive water. The drivers for leakage control are water company management policies governed by investment decisions based on the costs of leakage management, the water resources position and meeting regulatory and political objectives (as summarised in Table 2.2).

Leakage can be reduced by the four principal water company operational activities:

- locating leaks and bursts quickly;
- effecting swift repairs of good quality;
- reducing the pressure in the distribution system;
- in the longer term, replacing the mains that are bursting/leaking.

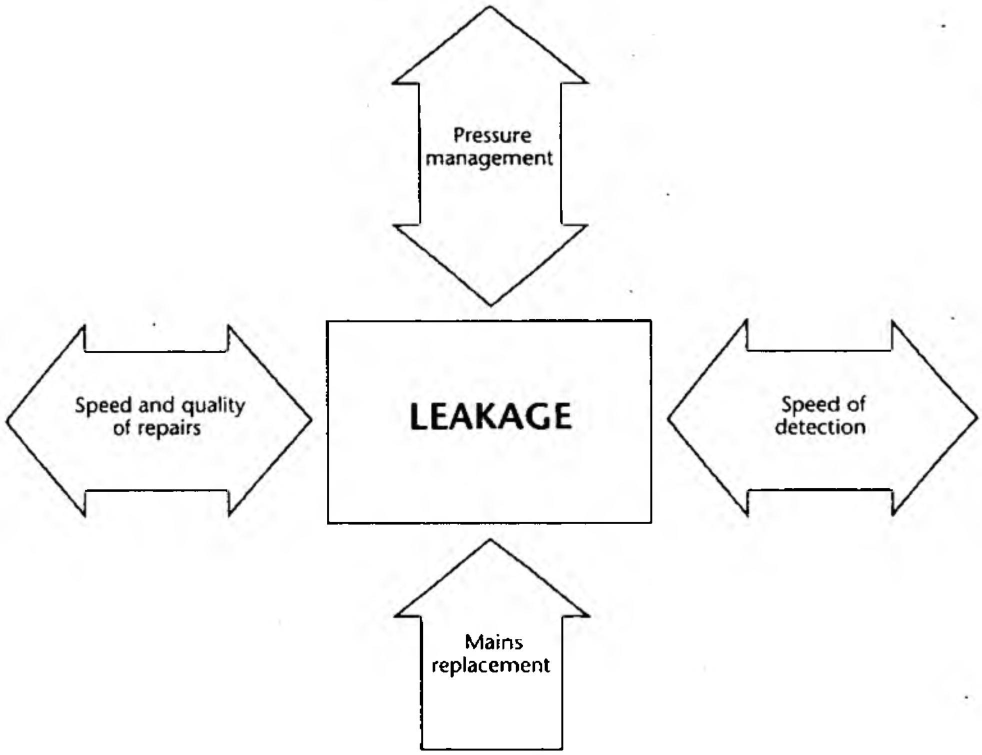
In Figure 5.1 leakage is represented by the area of the rectangle. The rectangle is naturally expanding in size, at its natural rate of rise (NRR), with the leakage management policies represented by the arrows holding it in check. The policies, speed of detection, speed and quality of repairs, mains replacement and pressure management act to reduce the size of the leakage rectangle. If pressure is increased to meet some improved pressure standard for customers (or speed of detection and repair are abandoned or relaxed) the leakage rectangle will expand. Lowering pressure reduces the volume of water flowing out of the existing holes and cracks, and reduces the burst frequency in the network.

The level of leakage where the expenditure on leakage control to save 1 m^3 of water is equal to the expenditure of providing 1 m^3 of water is known as the economic level of leakage or ELL. To reduce leakage below this level is deemed to be uneconomic although considerable areas of uncertainty remain, in particular the complexity of the calculation and the inclusion of social and environmental costs and benefits.

5.1.2 Components of leakage

The concept of leakage being made up of bursts and background components is accepted throughout the

Figure 5.1 Total losses and leakage management policies



water industry (UK Water Industry, 1994; Lambert *et al*, 1998). Bursts are large leaks, defined in *Managing Leakage* (UK Water Industry, 1994) as having flow rates greater than 500 litres/hour. These can be either reported (by the public) or unreported (found by active leakage control, or ALC). Reported bursts are generally repaired sooner than unreported bursts. Unless there is a robust ALC policy in place, unreported bursts can run for months or even years and so lose larger volumes of water.

Background leakage consists of smaller leaks, ranging from less than 10 litres/hour to 500 litres/hour and considered too small to be found by ALC. Background leakage can consist of a considerable proportion of the annual volume of losses, because they run continuously. Such leaks occur at joints and fittings, and in the initial stages of development of small corrosion holes (Lambert *et al 1998*). Since background leakage can be considerable, water companies need to have an integrated leakage control policy since the four methods referred to earlier (Figure 5.1) reduce different components of leakage.

Active leakage control requires measurement systems that alert the water company to the existence of new leaks. All water companies have sectorised their networks into discrete areas of 1,000-3,000 properties called district meter areas or DMAs. The district meter records flow into the DMA and by analysing the night flow the level of leakage can be assessed for action as part of the ALC policy.

If a water company operates a policy of repairing only "reported" (by the customer) bursts, defined as a passive leakage control policy, then generally leakage will rise from current levels at its NRR. Lambert *et al* (1998) reported that this lies in the range 0-20 litres/property/hour/year.

5.2 Forecast assumptions

The formulation of the leakage scenarios has focused in particular on the political and regulatory framework likely to influence the setting of leakage targets. High level changes in political and social attitudes will affect the priority given to leakage by government, which in turn, will influence the formulation of targets.

In Scenarios Alpha, Beta and Delta we have not considered directly the different components of leakage, nor the effects of different leakage management policies as set out in Section 5.1. Scenario Beta considers them indirectly, as both will have been considered in water company ELL calculations. Scenarios Alpha and Delta consider a predetermined outcome (rising leakage, 10 percent target respectively) rather than the effect of implementation (or non-implementation) of different leakage policies. In Scenario Gamma we have set standards for leakage control policies and, by using modelling techniques, have evaluated leakage levels resulting from those policies.

5.2.1 Forecast scenario assumptions

Scenario Alpha

Scenario Alpha is characterised by low levels of investment in the water industry, the high cost of capital, lack of technological innovation, weak regulation and the low priority placed on sustainability as a political objective (Table 3.1). In these circumstances leakage will rise, at its NRR if the company is still practising passive leakage control, that is responding only to bursts reported by its customers. The NRR will vary by water company, by water resource zone and by DMA. In the absence of company and zone-specific NRR data we have adopted the midpoint of the range suggested by Lambert *et al*, that is, 10 litres/property/hour/year. However, we have adopted a conservative approach and assumed that this rate of rise is only applicable to the first two years, from 2010-12, and that the subsequent rate of rise reduces to 2 litres/property/hour/year, consistent with the German city reported by Lambert *et al* (1998). From 2012-25, continuation of the NRR at 2 litres/property/hour/year, for most companies increases overall demands to levels that exceed existing deployable output.

In the short term such a policy would place excessive demands on the distribution network. Meeting such demands would cause serious pressure problems at the time of peak demand. To account for this we have capped leakage at 50 percent of distribution input, evaluated from base-year demand components. The cap is an upper limit based upon historical evidence that indicates leakage was allowed to rise to such levels in some areas of England and Wales. Once this level is reached, leakage is held at that level to the end of the planning period. Such high rates of leakage could have severe environmental consequences, but this is consistent with a scenario where the environment has a low priority and levels of investment are low.

Scenario Beta

Within this scenario, deregulation plays an important role with greater emphasis placed on market forces of competition. The system of setting leakage targets would be subject to reform, reflecting lower public and political expectations regarding leakage performance. Despite this, greater competition within the water industry would ensure that leakage is at least contained at a level set by economic considerations.

The high rates of metering (see Section 4.3.3) in this scenario do not significantly reduce supply pipe leakage. Firstly, in a market-led economy it is likely that the present trend of installing meters internally will accelerate. Secondly, infrequent meter readings will not be an adequate substitute for active leakage control. We do recognise, however, that some previously undetected leakage will be found at the time of meter installation. We have assumed that these gains will be negated by a slight increase in system leakage.

In their water resources plan submissions to the Agency in 1999 the water companies forecast their leakage levels to 2025. These were based on achieving their leakage targets within the period 2003-05, determined from their own assessments of their ELL. Annual leakage targets set by Ofwat are on the "glide path" to this ELL. Following achievement of this ELL, most companies forecast no or very minor deterioration from this position throughout the planning period. These leakage forecasts have simply been adopted for Scenario Beta with a downward adjustment consistent with the 2000/01 mandatory leakage targets.

Scenario Gamma

This scenario has strong, centralised regulation that sets leakage targets in the context of sustainable development, where there is a high level of investment into R&D of leakage control techniques allied to technological innovation and dynamic management. As a result, water companies adopt best practice techniques and are continually striving to reduce leakage.

Predicting leakage policies and technology 25 years hence is extremely difficult. We have assumed that methods that some water companies find cost-effective today are likely to be cost-effective for all water companies in future. We have considered future technological development but not costs directly, due to the high level of uncertainty.

In expecting water companies to achieve best practice levels of leakage it is necessary to consider the leakage policies. Simply because one company can reach a certain leakage level does not mean that another can: the second company may have many inherent disadvantages, for example, aggressive soils, variable relief, lower winter temperatures. We have modelled "best practice" policies using Bursts and Background Estimates (BABE) software. As the policies translate into Ml/day values we are able to understand the influence of different policies and the potential scope of leakage reduction. The detail of this modelling approach is described in Section 5.3.

Table 5.1 Timing of application of leakage scenarios

Scenario	2000 – 2005	2005 – 2010	2010 – 2015	2015 – 2020	2020 – 2025
Alpha	As WRPs		Passive leakage control policy		
Beta	As WRPs				
Gamma	As WRPs	Apply "best practice" policies			
Delta	As WRPs		Reduce total leakage by 1% per annum until 10% reached Then hold at 10%		

As WRPs = the leakage figure provided to the Agency in water resources plan submissions adjusted for Ofwat's 2000/01 mandatory target.

Scenario Delta

For Scenario Delta we have assumed that regionalisation, not just of government but of many previous national institutions including the trade body of the water companies, will result in leakage activity lacking any sort of national focus. As a result, the debate about leakage targets and performance indicators effectively ceases and performance is measured in the technically limited measure of percentage of distribution input. However, because water resources are managed locally with priority given to environmental issues, there would be a high consciousness of water efficiency and aggressive campaigns to reduce leakage.

In this scenario, different regional governments would adopt differing attitudes to leakage, with different expectations of, or targets for, leakage reduction. These different approaches may or may not be related to the water resource position in the region. In some areas at least, the expectations or targets would be primarily politically driven. Given limited available data we have not attempted to vary regionally the leakage expectation or target. Instead we have adopted a national leakage expectation or target of 10 percent of distribution input. A 10 percent target is demanding, especially as the decline in the other components of demand will require continuous and progressive leakage reduction in order to maintain leakage at the 10 percent level. We have assumed a rate of reduction of 1 percent per annum until 10 percent is reached. Thereafter, leakage is held constant at 10 percent although this is likely to represent further real reductions as the other demand components decline.

The average annual reduction of all the water companies over the last five years is 1 percent per annum. Some water companies have reduced their leakage at a much faster rate. In this scenario such rates of reduction will be maintained at lower levels of leakage, because of the political will to reduce leakage and the willingness of water companies to employ people on leakage control activities.

5.2.2 Timings

Scenarios Alpha and Delta, both based on regional systems of governance, are unlikely to impact upon the current regulatory approaches to managing leakage until 2010. Until then the forecasts simply adopt the water company leakage estimates provided to the Agency in their water resources plan submissions, adjusted for the 2000/01 leakage targets set by Ofwat. For Scenario Beta we have adopted the water company estimate throughout the planning period. The current interest in leakage targets and limits to leakage reduction has been reflected in Scenario Gamma where the adoption of "best practice" leakage policies is assumed to take effect from 2005.

5.3 "Best practice" leakage – Scenario Gamma

In developing "best practice" policies, three methods of reducing leakage have been considered:

- finding and repairing leaks faster (faster "find and fix");
- pressure management;
- services and mains replacement.

The effect of the policies on the two components of leakage, bursts and background has been considered, as shown in Table 5.2.

It is important to note that both pressure management and services and mains replacement are known to reduce the frequency of bursts. Across the water industry there is still uncertainty regarding the precise nature of these relationships. For this reason we have not included this within our modelling. The application of different leakage policies has been carried out using a BABE model (Lambert 1994). The majority of the data required to run the model (at whole company level) are published in Ofwat's annual report *Leakage and the Efficient Use of Water.* To these data, water company

Table 5.2 Relationship of leakage control methods to leakage components

Demand component	Bursts	Background
Faster "find and fix"	✓	
Pressure management		✓
Services and mains replacement		✓

average zone night pressures (AZNPs) as well as mains lengths and burst rates (which form part of the *"June return"* to Ofwat) have been added. Due to a lack of company-specific data the model uses a number of default values and assumptions that are reported in Appendix 4. The remainder of this section sets out the assumptions related to these three policies. The "find and fix" policy level includes a hierarchy of sub-policies which reflect different levels and intensities of activity.

5.3.1 Faster "find and fix" policy

The "run time" of a burst can be divided into three components, as defined by Lambert *et al* (1998):

- Awareness (A) – the average time from the start of a leak until the water company becomes aware that a problem exists, but without knowing its location;
- Location (L) – the average time it takes the water company to locate the leak once it has become aware;
- Repair (R) – the average time it takes to shut off or repair the leak, after it has been located.

By varying the awareness, location and repair times in the BABE model it is possible to assess the effect of different leakage control polices on the level of leakage. The relationship between awareness, location and repair times and the potential losses from different types of bursts is shown in Appendix 5. A supply pipe burst with a much lesser rate of leakage than, say, a mains burst can account for a greater total volume of leakage when a lower priority is given to bursts with lesser flow rates, because they will cause fewer problems to the water company in the short term.

The leakage policies are shown in Table 5.3, where the numbers represent the days applied to awareness, location and repair. The "run time" of the burst is simply the sum of A, L and R. Further explanation is provided in Appendix 5.

Policy 1 – district meters read weekly

Response times to reported bursts have been chosen to reflect what we consider a "reasonable" company policy. For unreported bursts, location times for trunk mains are based on once-a-year sounding which gives an average awareness time of half a year, that is, 183 days. ALR times for other reported bursts are consistent with Lambert *et al* (1999). The ALR times for unreported bursts we have assumed are shorter than those reported in Lambert *et al* (1999), principally because those values are based on "intensive active leakage control, approximating to night flows (or water balance) once per month on highly sectorised distribution networks". The main difference is that in this scenario the district meters are read weekly, in line with industry practice in most England and Wales water companies. Communication pipes and supply pipes have location times of 11 days, indicating that a second and confirmatory signal of a leak is required before the detection team is mobilised. Repair times are greater for unreported bursts, reflecting marginally less urgency.

Water company leakage comparisons

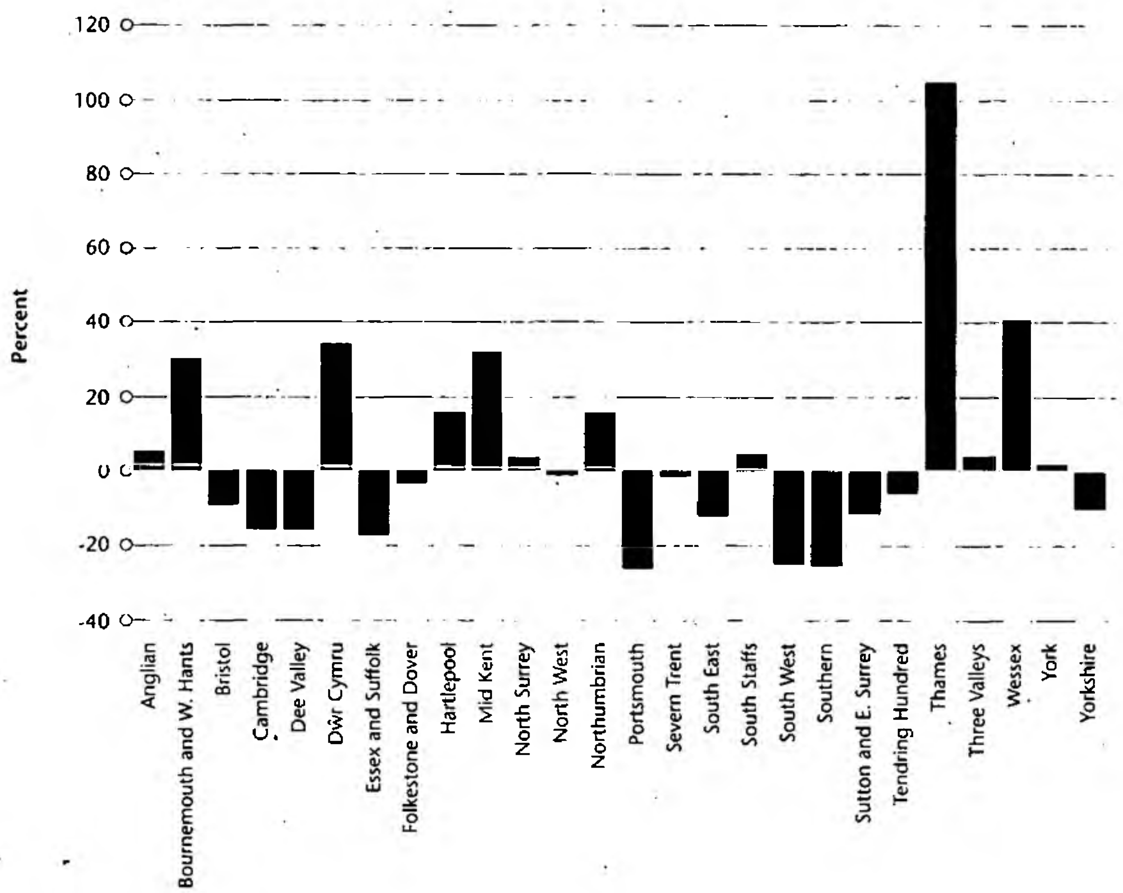
A leakage comparison is shown in Figure 5.2, where the total leakage (97/98) is compared with the leakage value given by the application of Policy 1 and the difference expressed as a percentage. The fact that 14 companies are "below the line" suggests that they are already performing better than Policy 1 (or the data overestimate the leakage level). If a company's Policy 1 figure exactly matched their total leakage figure, this would not mean that the data are robust and the company is exactly following Policy 1, since the same leakage level could be achieved by different variants of policy. However, this does give some degree of confidence that Policy 1 is representative of current company policies and practices. This exercise has been carried out using data in the base-year (97/98).
If repeated with more recent data (99/00), more companies would be "below the line" and for those above the line the difference would be markedly less as a result of recent progress in reducing leakage.

For those 14 companies, in the base-year and at subsequent time steps, the level of leakage determined from this exercise is greater than the level submitted in the water resources plan (with subsequent adjustment for Ofwat 2000/01 targets). Where this is the case the water resources plan figure has been adopted until the year that it is supplanted by a lower "best practice" figure determined from the modelling exercise. Without

Table 5.3 **Leakage policies (in days)**

		Trunk mains		Distribution mains		Communication pipes		Supply pipes	
		Reported	Unreported	Reported	Unreported	Reported	Unreported	Reported	Unreported
Policy 1	Awareness	0.2	0	1	4	1	11	1	11
	Location	0.3	183	1	2	3	14	4	14
	Repair	0.5	2	1	3	4	5	4	5
Policy 2	Awareness	0.2	0	1	0.5	1	7	1	7
	Location	0.3	52	1	1	3	3	4	4
	Repair	0.5	2	1	2	4	4	4	4
Policy 3	Awareness	0.2	0.5	0.2	0.5	0.5	0.5	0.5	0.5
	Location	0	0	0	0	0	0	0	0
	Repair	0.5	0.5	1	1	3	4	3	4

Figure 5.2 **Comparison of model output and actual leakage levels 1997/98**



this adjustment those 14 companies would, in the early years of the forecasts, have leakage targets/outcomes in excess of their existing leakage level, which would be inconsistent with this scenario.

Policy 2 – district meters on telemetry (read daily), noise loggers, swift repair

This policy is based on the use of acoustic noise loggers and a district metering system. For unreported bursts on trunk mains it is assumed that 50 percent are in or by roads that can be patrolled. Since awareness would be immediate if a trunk main burst was located, the sum of awareness plus location (A+L) is reduced to 15 days, half the time taken by a monthly "patrol" of loggers located on trunk mains. However the other 50 percent of trunk mains are assumed too difficult to reach (a conservative estimate) by vehicle, so they are only "walked past" or physically sounded every six months, giving an average A+L of three months. For unreported trunk mains bursts as a whole the average A+L time is therefore 52 days.

For distribution mains, ALR times for reported bursts remain the same as in Policy 1. Unreported bursts have an awareness time of, on average, half a day (reported by telemetry), a location time of one day (patrolling) and a repair time of two days. For communication and supply pipes it is assumed that a seven-day confirmatory period will elapse prior to location. Location and repair for communication pipes are three and four days respectively, recognising the additional difficulty of locating supply pipe leaks as suggested by Lambert *et al* (1999), where A+L+R for supply pipes was one day greater than for communication pipes. Repair times for both supply and communication pipes are four days.

Policy 3 – self-locating noise loggers on telemetry, reduced repair times, district meters only confirmatory

In this policy noise loggers "report" the occurrence of the leak (via telemetry) and locate it, for example, metres between logger Y and Z. The technology is a combination of the existing mobile leak noise correlator and acoustic loggers placed on the network (as in Policy 2). As a result awareness times are reduced to half a day and location times are all minimised to zero, accompanied by further but marginal reductions in repair times. With the operation of this policy there will be few reported bursts, since they will be located by the technology before the public are able to report them. As the combination of these two technologies is not yet available it is necessary to consider whether full-scale implementation of such a system with a high capital cost would be economic. We have assumed that such technology will form part of a "best practice" approach to leakage in the next 25 years, although not for all companies. The repair times for communication pipes and supply pipes are three and four days for reported and unreported bursts respectively, recognising a greater urgency given to reported bursts. No technological advances in repair technology and methods have been assumed.

Table 5.3 details leakage policies 1 to 3. There is evidence to support the thesis that such policies are converging with the concept of "best practice" leakage. Severn Trent Water is adding to its existing complement of 13,000 acoustic loggers a further 15,000. The aim was to cover 50 percent of the network by acoustic loggers acting in "sentry" mode by the end of the financial year 2000/01 (Kane, 1999). This effectively means that Severn Trent Water has already introduced a monitoring system that would allow the full implementation of Policy 2 on 50 percent of its network. South East Water is deploying acoustic loggers in both permanent and reactive modes. As a result they expect to reduce leakage by 5 Ml/day (from 32 Ml/day) in their Sussex and Kent areas.

In terms of finding and repairing leaks, Severn Trent's standard is 48 hours, with most completed within 24 hours (Kane, 1999). This is similar to the standard set by North West Water where average response times (from time leak is located to completion of repair) are currently being maintained at between two and three days (Pearson, 1999). Southern Water have set out their standard for repairing customer leaks by stating that 80 percent should be repaired in five working days, and the remainder within ten working days (Southern Water, 1999).

Policy progression

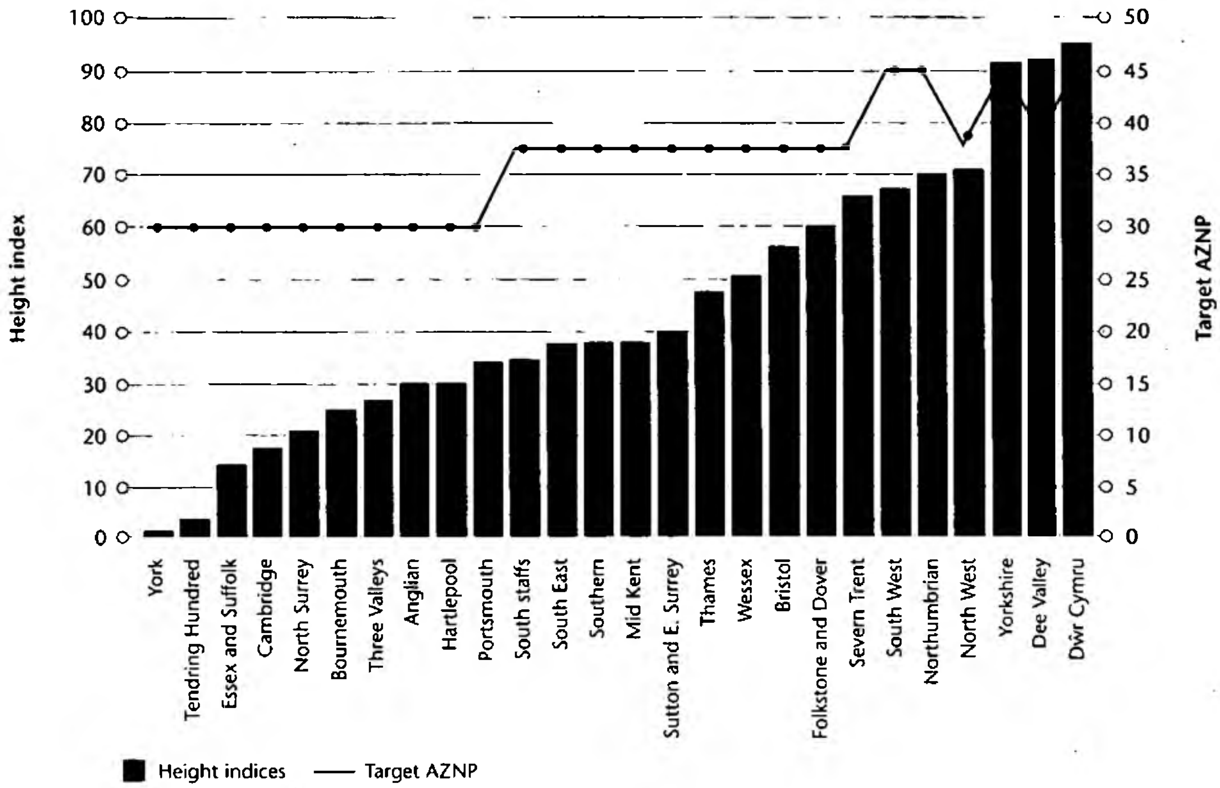
In our modelling we have assumed that water companies are currently operating at Policy 1 or thereabouts. The rate at which companies progress to Policy 2 and then 3 is based on an assessment of their resource position. Policy 1 is not a necessary precondition for policies 2 and 3 (acoustic loggers could provide effective leakage reporting without district meters) and Policy 2 (acoustic loggers) is not a necessary precondition for Policy 3 (self-locating acoustic loggers on telemetry). All companies are already at or close to Policy 1, so there is no case for a company going straight to Policy 2. However, implementing Policy 2 before Policy 3 for all companies recognises that:

- resource-stressed companies will install Policy 2 before Policy 3 is commercially available;
- water companies are likely to be conservative in their outlook and install what will then be the "tried and trusted" technology of Policy 2, which will also be less expensive in the short term;

Table 5.4 AZNP categories

Relief	Flat	Mixed	Hilly
Target AZNP	30m	37.5m	45m

Figure 5.3 Height index v target AZNP



- technological development may allow conversion of existing acoustic noise loggers to "self-locate" and report via a telephone link.

5.3.2 Pressure management

From water company ELL submissions to Ofwat and information provided directly to the Agency, it is evident that current average zone night pressures (AZNPs) vary by company from around 25 metres to 60 metres. When considering the scope for pressure reduction it is not appropriate to expect all companies to achieve an AZNP of 25 metres, the lower end of the company range. For example, while a single pressure reducing valve (PRV) in East Anglia could significantly reduce the pressure to, say, 4,000 properties, in the valleys of Wales 40 PRVs may be required to achieve the same result. The situation and hence scope for pressure management for most companies will lie within these two extremes. Buchanan (1998) showed that for a large grouping of DMAs in northern England the economic limit to pressure reduction was an AZNP of around 43.5 metres. Beyond this level the costs increased exponentially for small additional reductions in pressure. However this is likely to be related to the difficulty of reducing pressure in areas of variable relief, given that 11 water companies currently have stated or estimated AZNPs currently below this level.

To reflect the varying relief of different regions, water companies were categorised flat, mixed and hilly, with different AZNP targets for each (Table 5.4). From water resources plans we know that one company in the mixed category has set a target AZNP of 35 metres, below our suggested target. Buchanan's DMAs in "northern England" (Buchanan, 1998) can be categorised as "hilly".

The categorisation of water companies into flat, mixed and hilly was achieved by analysing the relief of company areas using a GIS. For each area an average height AOD (metres) was calculated. The proportion of land area for height bands, 0-20m, 20-40m, 40-60m.......180-200m, > 200m was then calculated. A height index was then calculated as follows:

$$HI = \sum_{i=1}^{n} (ABS\ (H_{ave} - H_{mid})\ A)$$

where:

HI = Height index
ABS = Absolute height
H_{ave} = Average height
H_{mid} = Height in middle of band
A = Percent of area in band

Table 5.5 **Background loss rates**

Component	Units	Average (average infrastructure condition)	Low (good infrastructure condition)
Distribution mains	l/km/hr	40	20
Comm pipes	l/prop/hr	3.0	1.5
Supply pipes	l/prop/hr	1.0	0.5

The height index, shown in Figure 5.3, is then simply the degree of spread from that average, so the greater the height index the greater the variability of relief. Where the variability of relief is high, the degree or amount of pressure reduction possible will be less. For a hilly company to achieve the same level of AZNP as a flat company will require far more pressure-reducing valves, supplying smaller areas at greater cost.

Figure 5.3 shows the companies arranged in order of ascending height index. To classify water companies into the three relief categorisations we chose height index values that divided the companies into the categories in a way that was consistent with our limited information on AZNP targets and economic limits for pressure reduction.

The relief categorisations are tabulated in Appendix 6. We have assumed that the rate for achieving the reductions in AZNP from the current position to the targets specified in Table 5.4 lies in the range of 1-3 m/year, dependent upon resource position.

5.3.3 Services and mains replacement

Table 5.5 shows the average background night flow losses as stated in *Managing Leakage* (UK Water Industry, 1994).

According to Lambert (1999) most DMAs now have background losses less than the 1994 *Managing Leakage* "average" value. As the mains in the DMAs with high leakage continue to be renewed the average figure will approach the "low" value. For modelling purposes it has been assumed that the improvement in background loss rates will be proportional to the rate of services and mains replacement, which will vary by resource position, but within the range of 1 percent per annum (resource category 3) to 3 percent per annum (resource category 1). In 1999/00 two companies renewed and relined over 3 percent of their network, with a further three companies renewing and relining more than 2 percent. The highest renewal rate alone was 2.4 percent. This suggests that water companies can operate their network with high renewal rates.
An increased level of services and mains replacement is consistent with Scenario Gamma, which is characterised by a willingness to invest in environmental projects and take a long-term perspective. It has been assumed that the replacement of supply pipes will be part of the water companies' mains renewal strategies (current policy for most companies is to renew mains and communication pipes but not supply pipes). In addition, we have assumed that water companies and the regulators would take a longer-term view when comparing the costs and benefits of mains relining with mains replacement (Conroy, 1997).

In reality the relationship between services and mains replacement and background leakage may not be linear if the water company targets the areas of highest leakage first, but in the absence of any information on this relationship it is proposed to treat it as such. The values used in the model can be found in Appendix 7.

5.3.4 Detailed timings of "best practice" policies

It seems reasonable to expect that water companies with the least headroom, and therefore likely to have the higher long run marginal costs of supply, would place a greater emphasis on reducing leakage. This would also be in line with public and political expectations. Hence the greater the resource problem the faster would be the introduction of "find and fix" policies, the annual rates of pressure reduction and service and mains replacement. We have assumed that much of this activity would begin now (2001/02) as pressure reduction generally has short payback times (based on operational costs only) and companies would substitute much of their planned relining activity with services and mains replacement.

The "best practice" policies have been applied as per Table 5.6.

Appendix 8, explains the placing of water companies into the three resource categories.

5.4 Scenario outcomes

The effect of each scenario on leakage is illustrated in

Table 5.6	Application of leakage policies

Resource category	Find and fix	AZNP	Service/mains replacement
Resource category 1 (Surplus <10%)	Policy 1 : 2000-2005 Policy 2 : 2005-2010 Policy 3 : 2010-2015	To target Rate: 3m/year, from 2000	Rate: 3%/year, from 2000
Resource category 2 (Surplus 10-20%)	Policy 1 : 2000-2010 Policy 2 : 2010-2015 Policy 3 : 2015-2025	To target Rate: 2m/year, from 2000	Rate: 2%/year, from 2000
Resource category 3 (Surplus >20%)	Policy 1 : 2000-2015 Policy 2 : 2015-2025 Policy 3 : not implemented	To target Rate: 1m/year, from 2000	Rate: 1%/year, from 2000

Figure 5.4 Total leakage, by scenario in 2010 and 2025

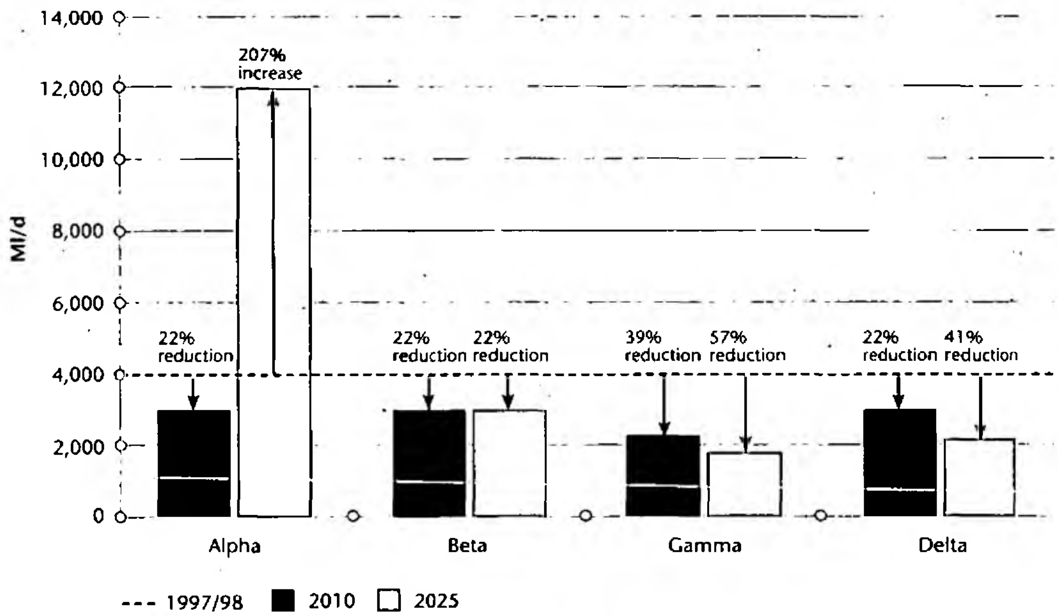


Figure 5.4. Compared to our current position, by 2010 the changes are quite small. By 2025 there are marked differences, with two scenarios seeing an increase while two decrease. In each scenario the combination of factors leading to these changes is different. In this section we address each scenario in turn and summarise how the changes in social values and systems of governance affect the drivers of leakage.

Scenario Alpha

This is a low-growth, low-investment scenario in which short termism predominates. Government regulation of the water industry is weak, with no political commitment to sustainable development. Investment in leakage control is curtailed. These characteristics are not evident until 2010, because there is a 22 percent decline in leakage from the base-year (1997/98) value. Up to 2010 the leakage forecast in the water resources plans have been adopted, adjusted for Ofwat 2000/01 targets. After 2010 active leakage control is abandoned and replaced by passive leakage control policies which result in a 207 percent increase from the 1997/98 base-year due to the natural rate of rise, which would have produced an even greater increase without the 50 percent (of distribution input) cap.

Scenario Beta

The water industry is subject to light levels of regulation. Given the primacy of market forces, leakage targets are not considered necessary, as the need to be competitive is assumed to promote sufficient incentive. Leakage control is not perceived as a critical issue in maintaining public water supplies. Throughout the planning period the leakage forecast for this scenario is taken from the water company water resources plans adjusted for the Ofwat 2000/01 target. As a result there is no significant change in leakage between 2010-25.

Table 5.7 **Leakage reduction attributable to policy options: Scenario Gamma**

Component	Policy	% of saving attributable to policy
Bursts	"Find and fix"	40%
Background	Pressure management services and mains replacement	35% 25%

Scenario Gamma

Sustainable development is accorded high political priority, and the water industry is strongly regulated to protect and enhance the environment. There is rapid technological innovation, with the Government placing a high priority on research and development. The leakage target setting process reflects innovative technical solutions. A 39 percent reduction from the base-year in 2010 is evident under Scenario Gamma where "best practice" leakage policies have been in place since 2005. From 2010 to 2025 there is a further 57 percent reduction from the 1997/98 base-year level. As this reduction (from 3,989 Ml/day in 1997/98 to 1,710 Ml/day in 2025) has been evaluated from component-based modelling, we can assess the contribution of the different leakage control policies (Table 5.7).

The results displayed in Table 5.7 support the need for an integrated leakage management policy, since 60 percent of the overall saving is attributable to reductions in background leakage.

Appendix 9 describes how, for Scenario Gamma, the water company level leakage reductions were disaggregated to water resource zone level.

Scenario Delta

Leakage control is given a high priority, although the decentralised system of regulation inhibits it. Capital constraints curtail investment in research and development, slowing development of innovative leakage control technologies. Like Scenarios Alpha and Beta, leakage to 2010 is taken from the water resources plans adjusted for Ofwat's 2000/01 target. The 10 percent target under Scenario Delta, based on a political judgement, yields a 41 percent reduction from the 1997/98 base-year.

6 The industrial and commercial demand scenarios

The forecasts of industrial and commercial demand for water consider both the non-household component of public water supply and the primary industry-manufacturing component of direct abstraction. The method and assumptions underpinning these forecasts are the same, with variation between the forecast models reflecting differences in the availability of base-year water-use data. In some industrial sectors, companies draw on both public water supply and direct abstraction. Although these sources are often used for different purposes within the industrial process, we do not draw this distinction within our forecast models.

This chapter is divided into five sections. Section 6.1 defines the core dimensions of the forecast model and the forecast method is outlined in Section 6.2. In Section 6.3 we discuss data issues, while scenario-specific assumptions are discussed in Section 6.4. The final section (6.5) presents the national demand scenario outcomes in 2010 and 2025.

6.1 The forecast model

To allow the application of scenario-specific assumptions to the key drivers of industrial and commercial demand outlined in Chapter 2, we identified three important issues that the forecast model should address:

- breakdown of industrial and commercial water consumption by sector: to allow the application of scenario-specific assumptions related to sectoral rates of growth and structural changes to the economy;
- development of a hierarchy of water-use minimisation measures: to allow the application of scenario-specific assumptions related to the implementation of water-use minimisation measures by industry and commerce;
- classification of businesses into small and medium sized enterprises (SMEs) and large companies: to address the variable rate of uptake of water-use minimisation measures by business within each scenario.

6.1.1 Industrial and commercial sectors

Indicators of economic growth are identified in the Foresight "Environmental Futures" framework, as are those sectors of industry and commerce likely to experience expansion or decline (DTI, 1999). To explore the impact of sectoral changes on water demand, it is recognised in the water industry that water consumption should be broken down into discrete sectors of industry and commerce (UKWIR/NRA, 1995). Rather than simply distinguishing between manufacturing and business (Mitchell, 1999; Mitchell *et al*, 2000), we have developed a disaggregated approach linked to the Standard Industrial Classification (SIC 92). On this basis we have broken down public water supply non-household use into 19 sectors related to the two-letter SIC (92) class (Table 6.1). For direct abstraction we have specified 11 sectors related to the four-digit SIC (92) division (Table 6.1).

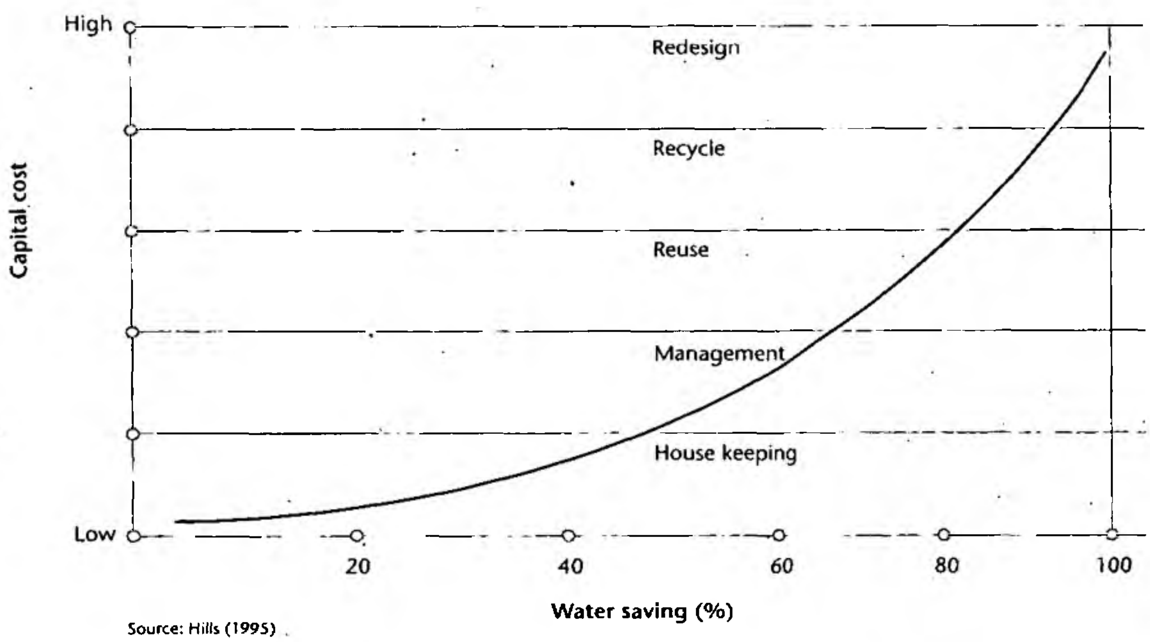
6.1.2 Water-use minimisation hierarchy

A wide range of water-use minimisation measures can be implemented within industry and commerce, with marked differences in capital cost, payback period and associated reduction in water use. The availability of capital for investment and the attitude of management to the environmental agenda will influence the types of measure used. To address these issues through the water demand scenarios, we have developed a hierarchy of water-use minimisation measures,

Table 6.1 **Industrial and commercial sectors included in the public water supply and direct abstraction forecast models**

Public water supply	Direct abstraction
Extraction	Chemicals
Utilities	Construction
Fuel refining	Extraction
Chemicals	Food and drink
Minerals	Machinery
Metals	Mineral products
Machinery	Metal manufacture
Electrical equipment	Pulp, paper and paper products
Transport	Recycling
Food and drink	Rubber
Textiles	Textiles
Wood	
Paper	
Rubber	
Construction	
Hotels	
Retail	
Education and health	
Other	

Figure 6.1 **Capital expenditure relationship to water saving**



Source: Hills (1995)

categorised on the basis of cost, payback period and associated reductions in water use (Figure 6.1).

The degree of management involvement demanded by each measure also varies, ranging from "fit and forget" technologies to those requiring sustained management commitment to maintain the level of reduction in water use.

To address these issues we have defined five water-use minimisation categories for production-based industries (Table 6.2). Using the same criteria but reflecting the different nature of water use within the service sector, education and health, we have specified three water-use minimisation categories (Table 6.3).

Using this classification system and drawing on information from a number of organisations such as Envirowise, we collated water savings for each sector (Appendix 10). In production-based sectors where information is limited, we have developed generic savings based on Envirowise literature. For hotels, hospitals and schools we have made a conservative assessment of potential reductions in water use, as currently only limited information is publicly available. This will improve with the implementation of the Buying Agency's Watermark project and the Environment Agency Wales' hotels benchmarking project.

Table 6.2 Water-use minimisation measures for production-based industries

Water-use minimisation measure	Cost	Payback period	Example measures
Good housekeeping	No to low cost	Immediate	Overflow identification; use of scrapers/squeegees before washing down.
Management	Low to minimal cost	Immediate	Monitoring and measuring devices to identify leakage; automatic shut-off valves.
Reuse	Low to medium cost	Less than 1 year	Reuse of water with no treatment – substitution for low-grade uses, i.e. washing down.
Recycle	Medium cost	1 to 2 years	Recycle water after treatment.
Redesign	High cost	3 years plus	Closed loop systems.

Table 6.3 Water-use minimisation measures for service-based industries

Water-use minimisation measure	Cost	Payback period	Example measures
Good housekeeping	No to low cost	Immediate	Tap re-washering.
Management	Low to minimal cost	Immediate	Monitoring of water consumption.
Water saving technology	Low to medium cost	Immediate	Installation of waterless urinals; installation of spray taps and low flow shower heads.

6.1.3 Uptake of water-use minimisation measures

A number of barriers to more widespread uptake of water-use minimisation measures have been identified in the literature. These barriers reflect not only the low value placed on water by businesses, but also the lack of organisational commitment to the environmental agenda, with management reluctant to allocate money and manpower to these initiatives (Baylis *et al*, 1997, 1998a & 1998b; Gouldson and Murphy, 1997, 1998; Rees *et al*, 1993; Rees and Williams, 1994). This is most marked in SMEs, which lag behind large companies in their understanding and approach to waste and water-use minimisation (Baylis *et al* 1997).

To explore the impact of different rates of uptake of water-use minimisation measures by SMEs and large firms, we distinguish in the forecast model between SMEs and large firms on the basis of numbers employed. In line with standard Office of National Statistics (ONS) reporting procedures, the companies within each SIC category are divided into three employment size bands, based on numbers employed:

- 0-99
- 100-299
- 300 +

6.2 Forecast method

On the basis of the three forecast parameters identified in Section 6.1, we assessed the applicability of the forecast methods reported in the UKWIR/NRA (1995) *Forecasting Best Practice Manual* and UKWIR/Environment Agency (1997) *Forecasting Water Demand Components: Best Practice Manual*. Lack of information and base-year water-use data played an important role in determining our approach (Table 6.4). Given that only one year's water consumption data were available for inclusion in the public water supply model, a number of methods were automatically excluded as they require a data time series of 10-20 years. In addition, a number of methods assume that the past is a good indicator of the future. Although this may be appropriate when forecasting short-term demand, it is not suitable when considering future scenarios. Within these constraints, we identified weighted output growth as the most appropriate forecast method.

Table 6.4 Review of forecasting methods for industrial and commercial water demand

Forecasting method	Water consumption data requirements	Approach to water efficiency	Appropriateness to a scenario approach	Time	Cost
Major water users survey	Provide up-to-date information on current water use, level of output and number of employees. Uncertainty over the accuracy of data requested over a longer time period.	Provide useful insight into current level of water efficiency by industrial sector and size of firm.	Questionnaire approach not a suitable vehicle to engage firms in the range of issues addressed in the scenarios. Difficulty of eliciting a response on the impact of key socio-economic changes on the future use and management of water within the firm.	9-12 months from project inception through to production of final results.	Expensive. Likely use of a market research company.
Trend analysis	A data series of at least 10 observations is required to ensure robust results.		This approach is based on the assumption that the past is a good indicator of the future. Although this may be appropriate when forecasting short-term demands, it does not avail itself to the application of the Foresight scenarios.		
Weighted output growth	Requires water consumption data for one year.	Allows the direct application of assumptions regarding water efficiency.	Allows the application of a range of assumptions linked to the key drivers of non-household demand.	Depends on level of industrial sector breakdown.	
Time series estimation by sector	Requires a 10-20 year time series of water consumption data, broken down by industrial sector.	Econometric approach allows the capture of any trends in water use efficiency.	Econometric analysis will assess the elasticity of water demand – in relation to changes in output, employment, water price and technical change.	Significant demands on staff time.	Requires purchase of detailed economic data.
Weighted output term	This method requires both disaggregated water consumption data for one year, and a time series of total non-household demand over a 5-10 year period.	Approach allows identification and analysis of any water-use efficiency trends.	Allows some analysis of the elasticity of water demand in relation to changes in output, employment, water price and technical changes.		
Projecting technical efficiency gains	Water billing data for one year is required.	Allows the explicit analysis of changes in the efficiency of water use.			Requires forecasts of economic growth and industrial input.

6.2.1 Forecast calculation: weighted output growth

Weighted output growth – for the base-year, the average water used per unit of economic activity is calculated. The weights are then applied to projections for output and employment to forecast water demand (UKWIR/Environment Agency, 1997).

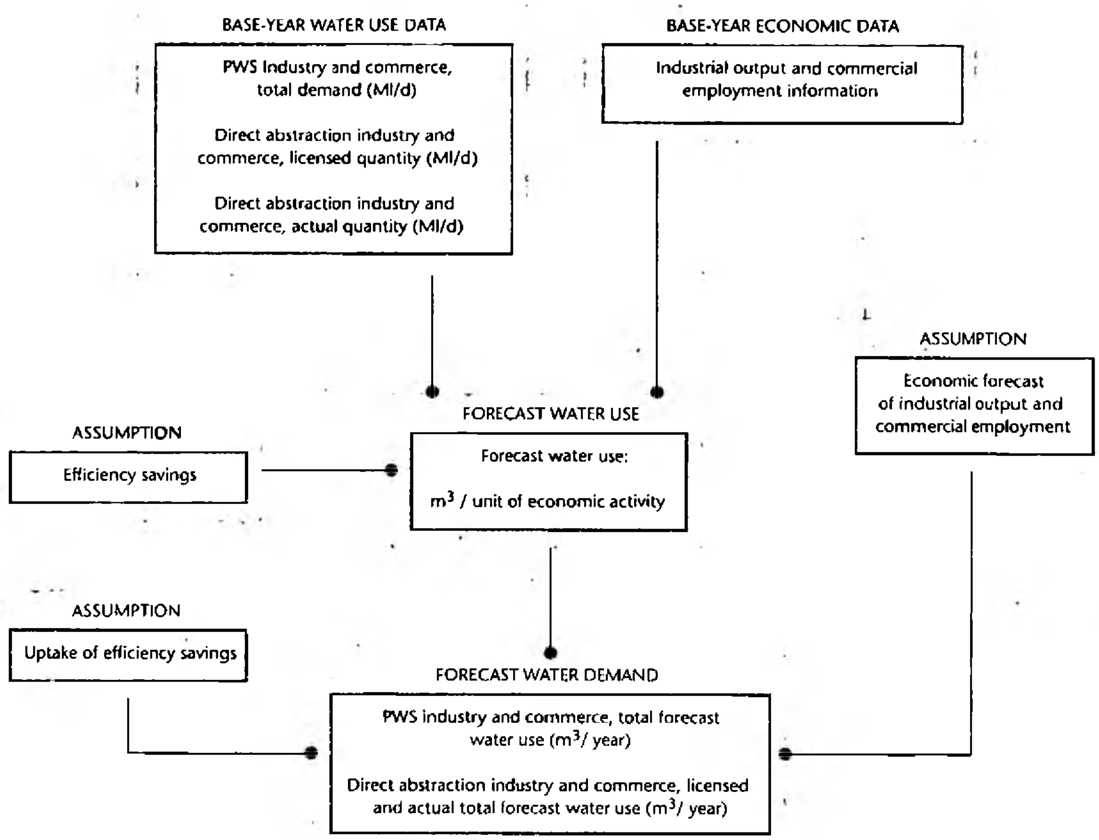
On the assumption that output is a suitable measure of economic activity for production-based industries, and employment for service-based industries, appropriate weights are calculated for the 15 production-based and four service-based public water supply forecast categories and the 11 production-based direct abstraction forecast categories.

The calculation can be split into three distinct stages: the generation of base-year water use in m^3/unit of economic activity; the generation of forecast water use in m^3/unit of economic activity and finally the generation of forecast water demand in m^3/annum (Figure 6.2). The key stages in this process are detailed below.

Base-year water use

- base-year water consumption and gross output/employment data are disaggregated into three company size bands, 0-99, 100-299, 300+, to allow differentiation in the application of water-use minimisation assumptions;
- weights are calculated to provide an average water use per unit of production/employment in each relevant size band for each forecast category.

Figure 6.2 **Key stages in the industry and commerce forecast process**



Forecast water use

- to reflect the impact of water-use minimisation measures, percentage reductions are applied to each relevant forecast category weight. To address variability in the rate of adoption of water-use minimisation measures, four levels of uptake have been defined – high, medium, low and no measures applied.

Forecast water demand

- to reflect the uptake of water-use minimisation measures, the proportion of businesses within each size band who adopt defined water efficiency measures in each forecast period is specified;
- to forecast future water demand, the change in output/employment per forecast category is applied to forecast water use per size band for high, medium, low and no uptake, to calculate a revised weight per forecast period.

Appendix 11 reports the calculation in detail.

6.3

Data sources

The forecast method draws on a number of information sources, reported in Appendix 12. Not all data sets were available in a consistent format or related to the same geographical scale, and consequently we had to apply a number of assumptions and additional calculations. These data issues are briefly discussed, including an assessment of the sensitivity of the results to these assumptions.

6.3.1 Base-year water use

Water consumption

The water company water resources plans provide information on measured, unmeasured and total non-household consumption (Ml/d), as well as associated properties and population. For the purposes of the water resources strategy, we asked water companies to provide a breakdown of total non-household consumption (Ml/d) into the two-letter Standard Industrial Classification (SIC, 92) categories for the

1997/98 base-year. Seventeen companies were able to provide information, but not all of them could break it down into the specified sectors. A combination of SIC (92) and the earlier SIC (80) classification systems was used, as well as categories unique to the billing system of the individual water company. Only the latter posed a problem, and in these circumstances the information was classified either as "other manufacturing" or "as business/services". For companies unable to provide a breakdown of non-household demand, a water consumption profile was estimated using information from ONS related to the number of businesses within each specified sector. This was reconciled against the water company's base-year non-household demand figure (Ml/d). This introduces a source of error into the public water supply non-household forecast, given that the profiles assume that all firms within a given sector conform to the "average" water consumption.

Information related to direct abstraction was obtained from the Agency's National Abstraction Licensing Database (NALD), which contains information on licensed abstractions in England and Wales. All licences are categorised on the basis of six primary categories: water supply; agriculture; industry, commerce and public sector; energy production; amenity and impounding. These are then subdivided into 52 secondary categories related to industrial sub-sectors such as chemicals, construction or food and drink, which are cross-tabulated against 48 use codes such as evaporative cooling or process water. In theory, it should be possible to cross-tabulate the total licensed quantity per secondary category against the use code, to target precisely water-use minimisation savings to specific uses of water. However, a large number of companies hold aggregate licences, where one licence quantity is split between a number of uses. Cross-tabulating secondary categories by use codes could have introduced a significant source of double accounting. The direct abstraction forecast model does not address this issue although, over time, improvements to the data should ensure that future direct abstraction forecasts incorporate this information. Of the secondary categories, 11 were related to primary industry and manufacturing.

All industrial and commercial direct abstractors are currently charged on the basis of licensed volumes, not the quantity of water actually used. The licensed volume recorded in NALD reflects the water usage which was justified at the time of granting the licence; actual usage may be considerably lower to reflect variation in the level of industrial output, changes to the pattern of production within the factory, and external factors such as the reliability and availability of water. To address this variability, and to understand the likely range of potential future demands, the direct abstraction model generates forecasts based on licensed and actual consumption. Using Environment Agency Wales data for the period 1994 to 1998, supplemented with information from South West and North East regions, an average actual water use figure was calculated for each secondary category. Using this data, a ratio of licensed to actual consumption is calculated for each secondary category. These ratios were applied to the 1997 secondary category licensed quantities for the eight Environment Agency regions. By applying such an approach, the forecasts of actual usage do not reflect regional differences within different industrial sectors.

Gross output and employment data

The administrative boundaries of the Environment Agency and those of the water companies are not standard ONS reporting boundaries. The lowest level at which ONS reports information is local government area such as county councils and unitary authorities. This creates a number of problems, as Agency regional and water company boundaries often cut across a number of local government areas, particularly in the case of small water-only companies. In these circumstances it was assumed that the businesses were distributed evenly across the area, and so the gross output was divided by the proportion of the local government area that the water company covered. We recognise that this is an unrealistic spatial assumption as it introduces a smoothing of what would be a discrete water use over a larger area. To address this issue in future revisions of the forecast we will need to cross-check water company data related to the number of properties within each SIC (92) two-letter category against the ONS data source.

ONS undertake to prevent disclosure of any individual business activities, and hence any analysis can be subject to data suppression. Although a two-letter SIC (92) category was used in the public water supply model, once again the data were suppressed particularly in the case of the small water only companies. This problem was related primarily to the extraction and utility forecast categories, and in these circumstances the base-year demand figure was maintained throughout the planning period. Consequently these forecasts do not reflect changes in the pattern of production.

6.3.2 Forecast water demand

Economic forecast of growth in gross output and employment

Forecasts of economic growth are a key input to our water demand model; the weighted output calculation proves particularly sensitive to changes in the level of gross output and employment. In this section we assess the variability of the Business Strategies Limited (BSL) forecast of gross output and employment against those produced by Cambridge Econometrics, to identify the likely sensitivity of our demand forecasts to changes in sectoral rates of growth.

Economic forecasts are available from a number of organisations including HM Treasury, city institutions and consultancies. Most of the models include core assumptions related to government monetary policy, as well as wider policies concerning European Monetary Union (EMU) and employment. Such factors influence projections of gross domestic product (GDP), gross output and employment. Given the influence of wider political processes on the development of national economic policy as well as the increasing global interdependence between financial markets, economic forecasts are subject to significant uncertainties. For this reason most of those available address short-to medium-term changes; short-term forecasts are produced on a quarterly basis, whereas medium-term forecasts relate to a 10-year period. Economic forecasts covering a 25-year planning period are rarely available from commercial organisations, because of the inherent uncertainties in developing assumptions related to the performance of financial markets and monetary policy over the medium to long term.

The BSL economic forecasts used in our water demand model cover the period from 1997 to 2009, whereas our demand forecasts cover the period from 1997 to 2024/25. Estimates for the years after 2009 have been derived by extrapolating the annual rate of growth for the period 1997-2009 for each sector. Under formal econometric modelling, the key forecast model components would extrapolate medium-term trends for each component over the longer term before running the model. We do not feel our approach was unreasonable.

Comparison of key economic indicators derived from the BSL and Cambridge Econometrics models over the period 1997 to 2009 reveals that GDP, manufacturing output and employment follow a similar growth trend over the period. At the industrial and commercial sector level, comparison of the national rates of growth projected by these models indicate that for most sectors the direction and rate of change are broadly similar. In particular, there is a close match between those sectors with negative rates of growth. For example, heavy manufacturing industries such as basic metals, metal goods and mining are projected to decline in both economic models. Given this conformity, the use of alternative economic forecasts would not materially affect the results of our water demand forecast.

BSL's national forecast is built up from its regional projections. Regional economic forecasts of GDP, gross output and employment reflect the industrial geography of England and Wales. The degree to which different sectors contribute to regional GDP varies quite significantly (Table 6.5), and this will play an important role in determining future rates of growth. The regional economic forecasts were subjected to an internal review, and in most cases the projections conformed to broad regional trends. The only exception was the mineral extraction sector in Anglian Region; here the projected rate of growth did not conform to the local mineral plans. In this case we adjusted the forecast to maintain a constant rate of growth across the planning period.

6.4 Forecast scenario assumptions

Table 3.3 reports our assessment of the impact of the four scenarios on the key drivers of industrial and commercial demand. This provides the framework for the development, by scenario, of sector-specific assumptions related to:

- rate of uptake of water-use minimisation and types of measure implemented;
- rate of growth in gross output and employment.

These are detailed in Appendix 13. This section will outline the guiding principles underpinning our development of scenario-specific assumptions and associated growth factors.

6.4.1 Water-use minimisation forecast assumptions

As noted in Chapter 3, a combination of market and state processes of regulation influence the decision-making of householders, businesses and farmers. In the context of industry and commerce, the rate of uptake of water-use minimisation measures will be directly influenced by environmental regulation as well as indirect pressures within the business such as the drive for business efficiency and cost minimisation. Incremental processes of change, reflecting shifts in the priorities and values of wider society, will also play a

Table 6.5 Sectors contributing to regional output

Agency Region	Government office region	Top three manufacturing sectors contributing to regional output
North East Region	North East	Chemicals and man-made fibres 17% Basic and fabricated metals 15.4% Food, drink and tobacco 12%
North East Region	Yorkshire and Humberside	Metals 16.3% Food, drink and tobacco 16% Chemicals 12.2%
Midlands Region	West Midlands	Metals 20% Transport equipment 19.2% Machinery and equipment 12.7%
Midlands Region	East Midlands	Food, drink and tobacco 17.8% Textiles and clothing 13.4% Transport equipment 11.1%
North West Region	North West	Chemicals and man made fibres 18.3% Food, drink and tobacco 14.1% Printing and publishing 9.7%
Environment Agency Wales	Wales	Metals 20.9% Electrical engineering 15.6% Food, drink and tobacco 11.4%
Anglian Region	Eastern	Food, drink and tobacco 15.9% Electrical and optical equipment 15.5% Paper, printing and publishing 13.3%
Thames and Southern Regions	South East and London	Paper, printing and publishing 24.1% Electrical engineering 15.7% Chemicals and man-made fibres 13.3%
South West Region	South West	Electrical and optical equipment 16.4% Transport equipment 14.9% Food, drink and tobacco 14.8%

Source: CBI (1999)

role, as these gradually (re)shape the attitudes and priorities of businesses. Hence implementation of water-use minimisation measures by businesses may be reactive, in response to new state regulations or an increase in the price of water. Alternatively they may adopt a more proactive approach motivated by their corporate commitment to the environmental agenda, or recognition of the competitive advantage of marketing their green credentials. Identifying those processes is extremely difficult. Given the current low levels of uptake across industry and commerce, little information is available to quantify the factors to which businesses are responding.

Chapter 2 identified the barriers to widespread implementation of water-use minimisation measures by industry and commerce. Using these specified barriers as a starting point, we have assessed the degree to which they would potentially be overcome or mitigated within each scenario (Table 6.6).

We have assumed that organisational and managerial commitment are the main factors determining businesses' willingness to implement water-use minimisation measures. Securing this commitment is a precursor to gaining access to capital for investment and the allocation of staff time to water-use minimisation projects. The factors triggering the shift in organisational culture and management prioritisation of water use are diverse and include "greening of business initiatives" such as EMAS and ISO 14001, as well as increases in the cost of water and wastewater treatment. Such factors have influenced the assessments reported in Table 6.6 and inform the differential rates of uptake reported in Appendix 13. Once managerial commitment has been established, the availability of capital for investment and/or staff time will determine the types of water-use minimisation measure actually implemented.

The hierarchy of water-use minimisation measures outlined in Section 6.2 categorises, for each sector, likely reductions in water use resulting from the implementation of each type of measure. All the reported reductions are technically feasible today. Hence for each sector the water-use reductions under each measure are held constant across all four scenarios. Variability between scenarios is introduced by

Table 6.6 **Barriers to uptake of water-use minimisation by businesses**

Specified barrier	Scenario Alpha	Scenario Beta	Scenario Gamma	Scenario Delta
Organisational commitment to the environment	Low	Low	High	High
Managerial responsibility for water-use	Issue not considered by management	Management responsibility dispersed	Clearly defined responsibility	Clearly defined responsibility
Water costs as a proportion of total production cost	High	Medium	Medium	Low
Willingness of management to allocate capital for investment in water-use minimisation initiatives	Low	Medium	High	Medium-low
Willingness of management to allocate labour to water-use minimisation projects	Very low	Low	Medium	High

distinguishing between the types of measure implemented in each forecast period and their rate of uptake by business. For example, businesses with limited capital for investment may only implement "good housekeeping" or "management" measures that require no capital and generate reductions in operating costs almost immediately. Reuse or recycling measures would require capital investment that could prove unattractive to companies operating in an insecure climate or one with high business rates. The Foresight framework indicates the degree to which business commitment to the environment (in response to government policy, a reflection of wider changes in social values and attitude to capital investment programmes) will vary in each scenario.

6.4.2 Economic growth forecast assumptions

Given the inherent uncertainties in economic forecasting over a 25-year period, we have not undertaken detailed econometric modelling to develop scenario-specific economic forecasts. To achieve this would require detailed modelling and development of core assumptions about the performance of the economy. Instead we have adopted a simple approach that draws on the key economic indicators and story line set out in the Foresight framework.

The BSL forecasts of gross output and employment reflect core economic modelling assumptions related to GDP, inflation and interest rates as well as trends in government policy related, for example, to EMU. The assumptions and the resulting sectoral rates of growth in gross output and employment are detailed in Section 6.3. These forecasts have been used as a "baseline scenario" to indicate how current trends in the economic cycle and government policy priorities will impact on employment and gross output within each sector over the planning period. Rather than simply substituting the baseline for one of the four scenarios, it is used as a reference point and adjusted for each scenario to reflect the differences in GDP growth and structural changes to the economy (that is, identifying the sectors experiencing expansion or decline).

Development of these scenarios and sector-specific growth factors reflects an assessment of the relative differences between each scenario and the baseline. This assessment considers not only differences in levels of GDP but also sectors of the economy that are expanding or contracting. The "Environmental Futures" framework indicates that GDP ranges from a high of 3 percent under Scenario Beta to 1.5 percent under Scenario Delta; the baseline scenario represents GDP of 2 percent (Appendix 13).

Key differences relate to the sectors that are expanding or contracting under each scenario; the different amounts of water used within each sector will have major implications for our water demand scenarios. For example, within the chemicals sector there are marked differences in the rate of growth between Scenario Beta and Scenario Gamma. Under Scenario Beta the chemicals sector is an area of rapid growth, whereas a slower rate of growth is specified under Scenario Gamma.

Figure 6.3 Public water supply, industry and commerce, by scenario in 2010 and 2025

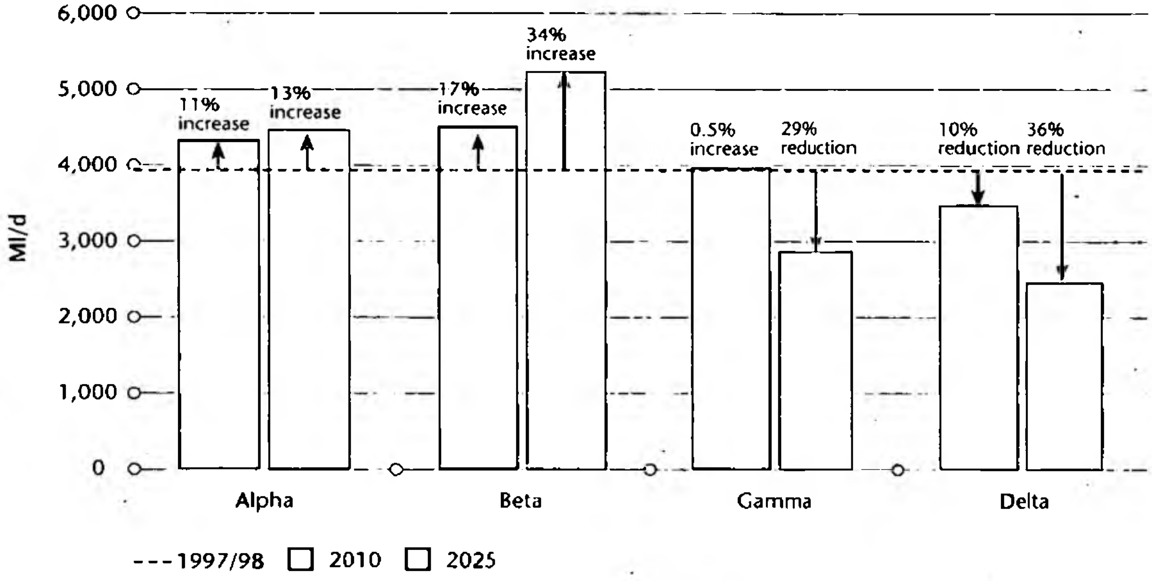
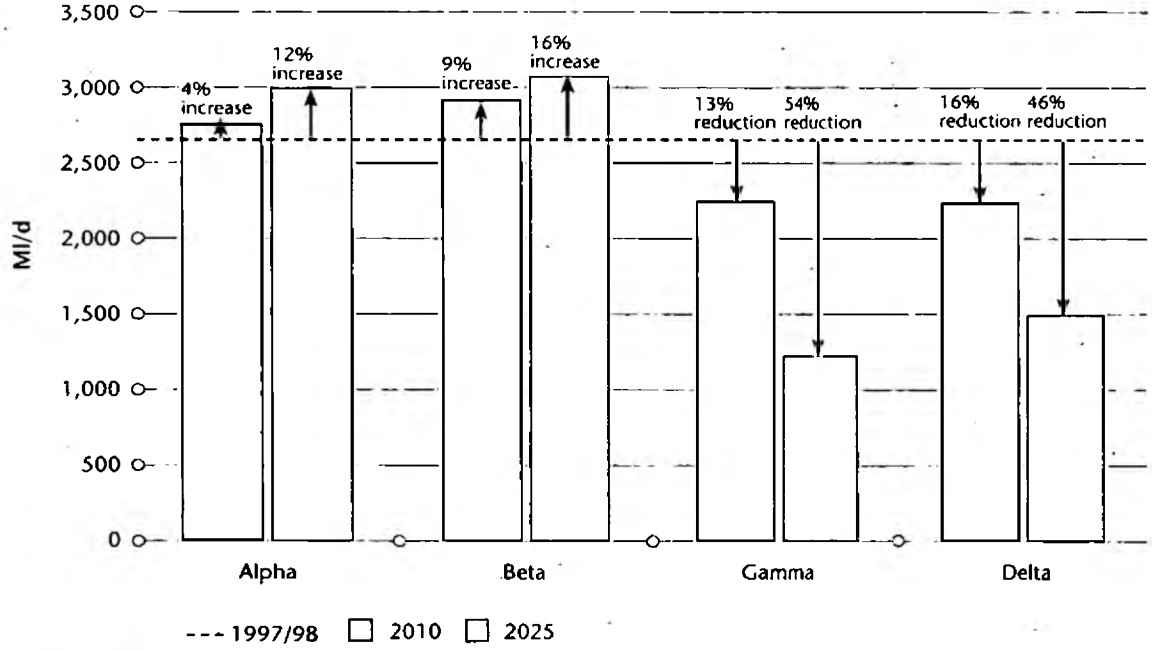


Figure 6.4 Direct abstraction, industry and commerce, by scenario in 2010 and 2025



6.5

Scenario outcomes

Figures 6.3 and 6.4 show the effect of each scenario on total industrial and commercial demand. Compared to our current position, by 2010 the changes in demand are quite small. By 2025 there are marked differences, with two scenarios seeing an increase in demand while two decrease. Figures 6.5 and 6.6 show how demand for water changes in some of the key industrial and commercial sectors under each scenario. In each scenario the factors leading to these changes are different. In this section we look at each scenario in turn and summarise how the changes in social values and systems of governance impact on the drivers of industrial and commercial demand.

Scenario Alpha: The political climate results in declining levels of both imports and exports. Sectors such as chemicals, business services and electronics face slower rates of growth after 2005, reflecting the reorientation of production away from international markets. This is counter balanced by growth in primary

Figure 6.5 Breakdown of public water supply, industrial and commercial demand, by key sectors, by scenario in 2010 and 2025

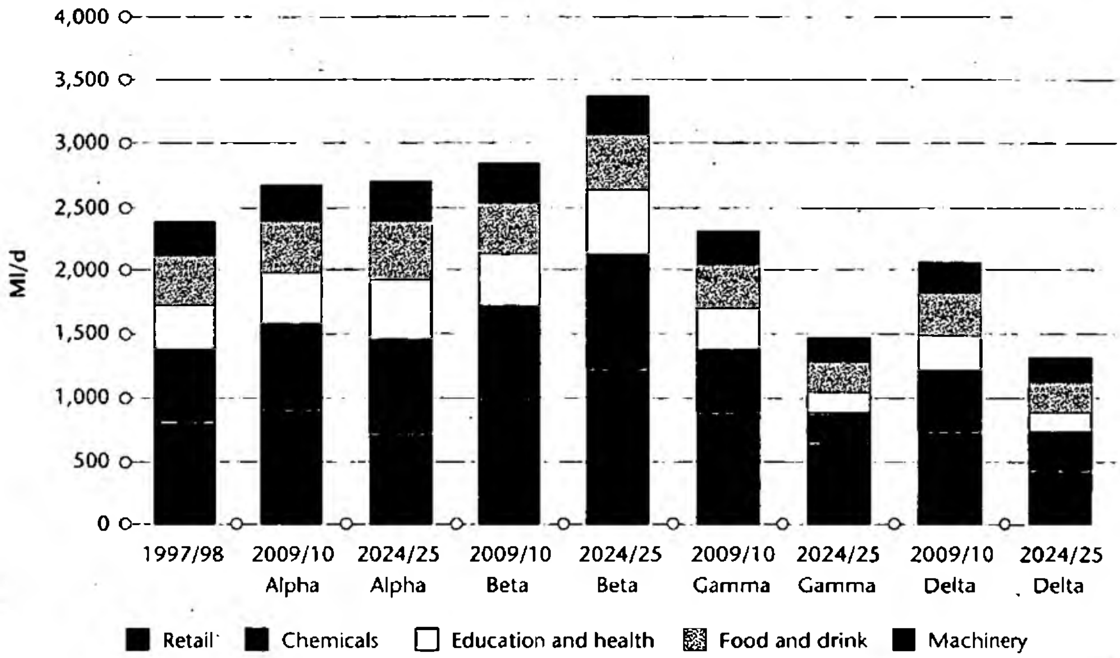
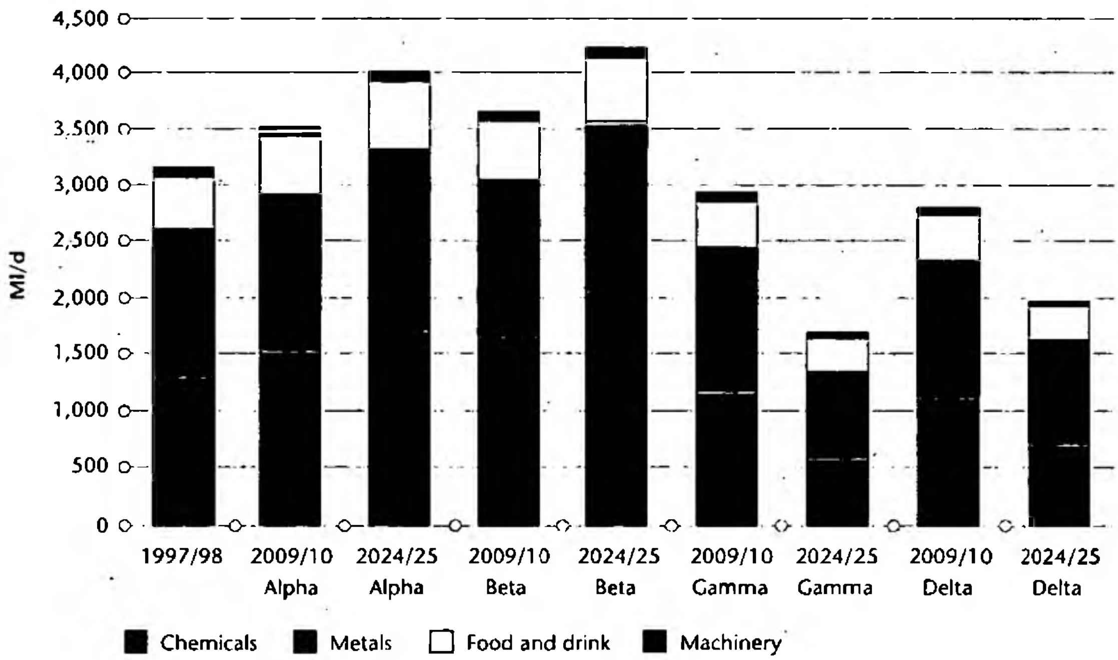


Figure 6.6 Breakdown of direct abstraction, industrial and commercial demand by key sectors, by scenario in 2010 and 2025



industry and manufacturing industries, such as metals, textiles and engineering, where long-term changes to the structure of the economy are slowly reversed. There are very low levels of uptake of water-use minimisation activity, compounded by lack of investment in manufacturing infrastructure.

Scenario Beta: The removal of all international trade barriers results in a reduction in gross output and employment within UK-based primary manufacturing industries such as textiles, machinery and metals. This decline is balanced by increased output and employment within business services, chemicals and biotechnology. Given the drive towards technological innovation we assume that, by 2025, 20 percent of firms across all sectors will implement low cost water-use minimisation measures such as good housekeeping, management and reuse options. This only partially suppresses the demand generated by the high levels of growth within the commercial sectors.

Scenario Gamma: Resource-intensive systems of production such as paper, minerals, rubber, textiles, metals and fuels are subject to stricter environmental regulations from 2010. These emphasise water efficiency, and affect 90 percent of businesses within these sectors. Other industrial and commercial sectors adopt voluntary measures to minimise their impact on the environment, with 50 percent of businesses within retail, business services and construction implementing good housekeeping and management measures by 2025.

Scenario Delta: From 2009/10 retail and business services and the leisure industry decline, reflecting the shift in consumer attitude. Industries such as chemicals, a high-water-using sector, also decline, in part reflecting the shift towards organic systems of agriculture. The environment is placed at the centre of industrial and commercial decision making, with eco-efficiency driving the decline in raw material use. By 2025, 65 percent of firms across all sectors have implemented low-cost good housekeeping measures, but more expensive measures such as plant redesign are inhibited by lack of available capital for investment.

7 The spray irrigation demand scenarios

As part of the development of the national and regional water resources strategies, we commissioned Cranfield University at Silsoe to develop a forecast model to predict changes in demand for spray irrigation water. The method builds on two previous Environment Agency R&D projects, *The optimum use of water for industry and agriculture: Best Practice Manual* (Environment Agency 1998b) and *Spray irrigation cost benefit study* (Environment Agency 1997b). This chapter outlines our new forecast method, and demonstrates how we have applied scenario-specific assumptions to the drivers of spray irrigation demand.

This chapter has five sections. Section 7.1 outlines the revised forecast methodology and compares the results of crop forecasts based on optimum and economic demand. Section 7.2 discusses issues related to base-year data and other information feeding into the forecast. Section 7.3 sets out the principles underpinning the development of our scenario-specific assumptions. Section 7.4 shows how we calculate the effects of climate change on crop water requirements. The final section (7.5) presents the outcomes of the spray irrigation demand scenarios in 2010 and 2025.

7.1 Spray irrigation forecast method

Comparison of licensed and actual spray irrigation abstraction volumes indicates that, even in dry years, the actual quantities applied are much lower than licensed (Figure 7.1). A combination of factors explains this difference:

- in dry years actual demand may be severely constrained if licence holders are unable to abstract their full licensed quantities due to limitations in the availability or reliability of abstraction;
- the actual volume applied may be influenced by equipment capacity constraints or shortage of farm labour;
- in any year the licensed quantity will include a proportion that is un-used. This will reflect normal seasonal rotation restrictions, as well as farms that permanently cease irrigation because they to restructure their cropping system.

In reality the use of irrigation water at the farm level will reflect individual farmer assessments of the economics of production, equipment constraints and water resource availability. For these reasons actual usage will rarely match the volumes recommended in standard irrigation scheduling plans.

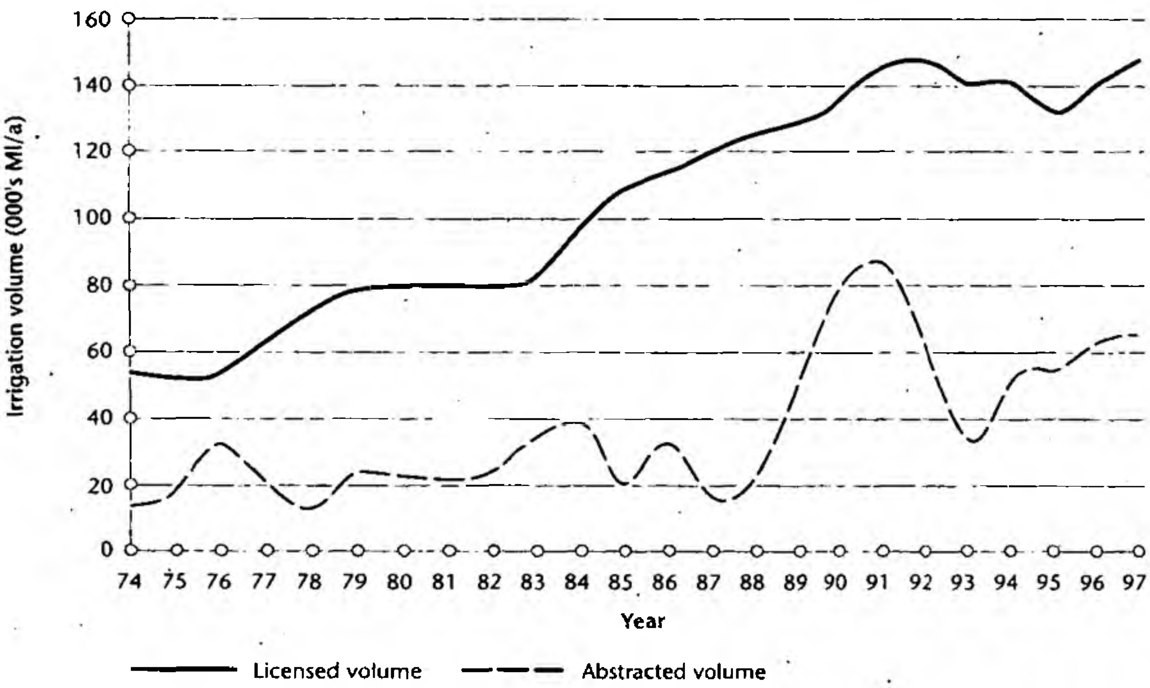
Previous forecasts have failed to address these issues. They have been calculated on the basis of the amount of water that individual crops should be given when following standard recommended irrigation plans to maximise crop yield and quality, termed "optimum demand". Consequently, these forecasts overestimate the level of demand for spray irrigation water.

To address these issues, we have developed a forecast method which calculates the relationship between "optimum demand" and the amount of water that irrigators should aim to apply given particular cost, price and other constraints (but excluding water shortage), termed "economic demand".

7.1.1 Optimum demand

The method developed in the R&D project *Optimum use of water for industry and agriculture: Best Practice Manual* offers a scientifically-based way of estimating optimum irrigation water requirements. The approach takes into account local soil type, crop type, standard

Figure 7.1 Comparison of licensed and actual spray irrigation demand 1974-97, Anglian Region



recommended irrigation plans (for that crop on that soil), and local climate. It estimates seasonal irrigation need, in terms of the depth of water (or volume per unit area) needed to obtain optimum production in 80 percent of years.

Optimum demand values have been calculated for 23 crop categories related to:

- three different soil types – representing soils of low, medium and high available water capacities (AWC);
- seven agro-climatic zones – defined on the basis of Potential Soil Moisture Deficit for grass (PSMDg).

The methodology does not consider capital, labour, equipment or water resource constraints. Furthermore, it does not take into account the costs and benefits of irrigating, other than where implicit in the recommended schedules. In many situations the benefits of irrigating a crop, though positive, may not be sufficient to justify the investment and risk. In other cases, decreasing returns to irrigation may only justify investment in a lower level of irrigation capacity.

Although the reported "optimum demands" for each crop are not fixed (for example, scheduling recommendations or climate may change), they are independent of individual farm and water resource factors, and thus relatively stable. They therefore provide a useful first stage for calculating economic demands.

7.1.2 Economic demand

Our new forecast method estimates the ratio between the economic demand and the optimum demand for selected crops, under different economic and water resource constraints. The method assumes that water resource constraint and/or low economic returns will limit on-farm investment in seasonal capacity (total licensed abstraction and/or reservoir capacity) and in peak application rate (pump and pipeline capacities, number of hosereels, etc.). These constraints will limit irrigation, depending on each year's weather pattern, with the greatest effects occurring in years with highest demand. The reduced level of irrigation results in a reduction in crop yield and quality, and hence farm income.

Once investment is made, it is assumed that the irrigator will try to follow the same schedules as for optimum demand. No allowance is made for "deficit" irrigation while irrigation is available; this is reasonable given the low marginal cost of irrigation for typical UK systems and the uncertainty over when declining returns to irrigation start. For simplicity, farms are modelled as single crop systems; that is, the irrigator does not choose which crop to irrigate. This is a gross simplification, and does not address secondary crops.

Calculation of the ratio of economic to optimum demand is broken down into six steps:

i for selected crop/soil/site combinations and specified equipment, peak-flow capacity constraints are calculated for water use in an average year, dry year and average levels of water stress;

ii the impact of specified irrigation constraints on crop yield and quality is estimated;

iii the difference (mm) between the average unconstrained and constrained demand, at the given equipment level, shows the impact of those constraints on water use;

iv using the outcome of step ii, the average benefit of irrigation (£/ha) for the given equipment level is calculated;

v using the outcome of step iii, the average cost of irrigation (£/ha) for the given equipment level is calculated;

vi the net irrigation benefits are calculated (£/ha).

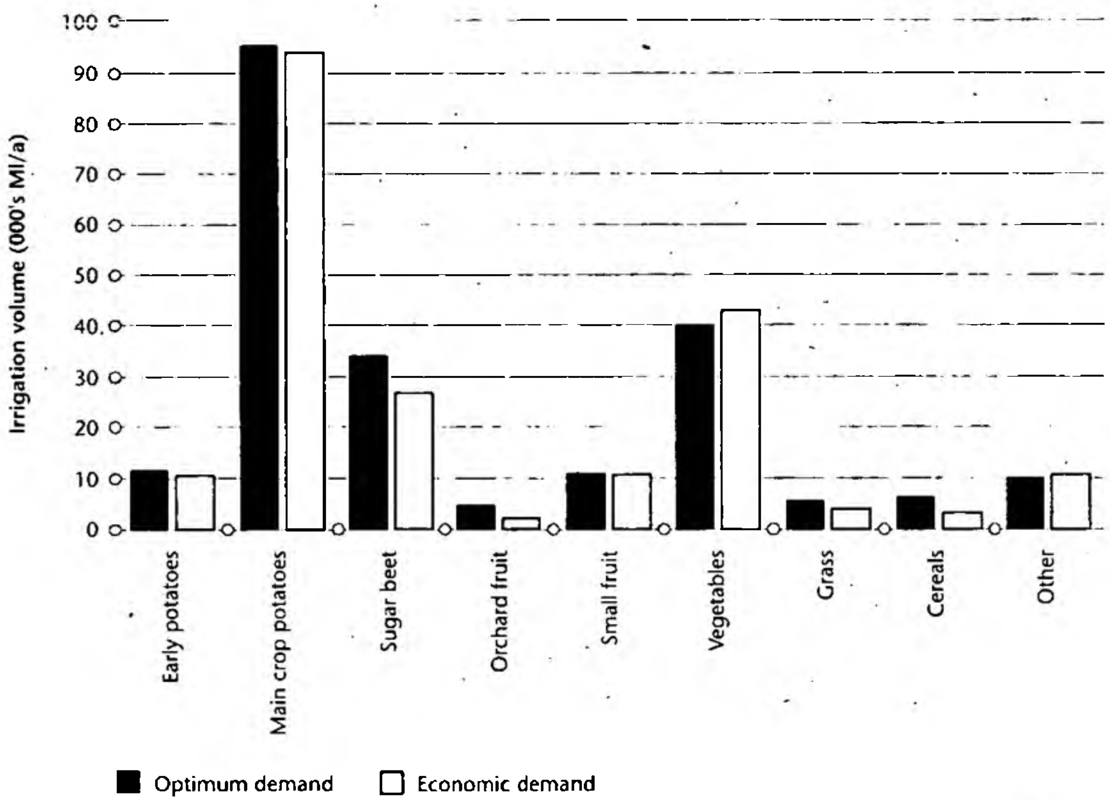
The highest net benefit is assumed to correspond to the economic demand (mm). The ratio of economic to optimum demand is then calculated for input into the forecast model. Appendix 14 gives further details of this calculation method.

7.1.3 Comparison of economic and optimum demand forecasts

Using the same baseline scenario assumptions, we can forecast water demand per crop category using both the economic and optimum calculation methods. The results demonstrate that for those crops recognised as high value, such as main-crop potatoes and vegetables, the benefits of irrigation are such that it is economic to apply the optimum irrigation requirement (Figure 7.2). In contrast, for lower value crops such as grass, cereals and sugar beet, economic demand is significantly below the optimum level. This suggests that the benefits of irrigation, in terms of additional yield and quality, do not warrant application of the full optimum irrigation requirement. In terms of irrigation, these secondary crops receive irrigation only when the primary crops, such as potatoes, have been fully irrigated.

Analysis of economic and optimum demand confirms the importance of focusing irrigation on crops that generate the highest economic return. As a basis for forecasting long-term demand the method proves reasonably robust. Further analysis planned under phase

Figure 7.2 Comparison of optimum and economic demand, by crop



three of the Agency's R&D project *Optimum use of water for industry and agriculture : Best Practice Manual* will refine the calculation of economic demand, and will be incorporated in future revisions of our spray irrigation forecasts.

7.2

The spray irrigation forecast model

Within our forecast model we have assumed that two main factors determine demand for spray irrigation water:

- area irrigated (ha);
- depth of water applied (mm).

These two components can be broken down into seven micro-components (Table 7.1), which relate to eight crop categories:

- main crop potato;
- early potato;
- sugar beet;
- vegetables for human consumption;
- soft fruit;
- orchard fruit;
- grass;
- cereal.

Table 7.1 The micro-components of spray irrigation demand

Area irrigated (ha)	Depth of water applied (mm)
Total crop area Crop yield Crop prices and quality premium	Optimum irrigation need Ratio of economic to optimum need Cost of irrigation Irrigation application efficiency

For each crop category, information related to the seven micro-components feeds into the base-year to calculate irrigated area (ha) and depth of water applied (mm). To forecast these, factors related to each crop category are applied to each micro-component. These two components are then multiplied to calculate the water volume (Ml/a) per crop category, which when aggregated provides total spray irrigation demand (Ml/a). The equation is summarised below, while Figure 7.3 summarises the forecast process.

Irrigation depth = optimum irrigation need x ratio of economic to optimum need x application efficiency

Irrigated area = crop area x proportion of crop irrigated

Irrigation depth x irrigated area = irrigation volume

7.2.1 Base-year spray irrigation data

The 1995 MAFF irrigation survey represents the best available information on spray irrigation in England and Wales. This data set, reported at county level, has been aggregated to Agency regional boundaries using an existing method (Weatherhead *et al*, 1994), to provide total crop area, irrigated area and volumes applied. The proportion irrigated and depths of water applied are calculated directly from this information. A GIS-based method has been used to calculate the optimum demand values for each region, weighted for crop location, soil type and agro-climatic zone. Appendix 15 gives this base-year information broken down by Agency region and crop type.

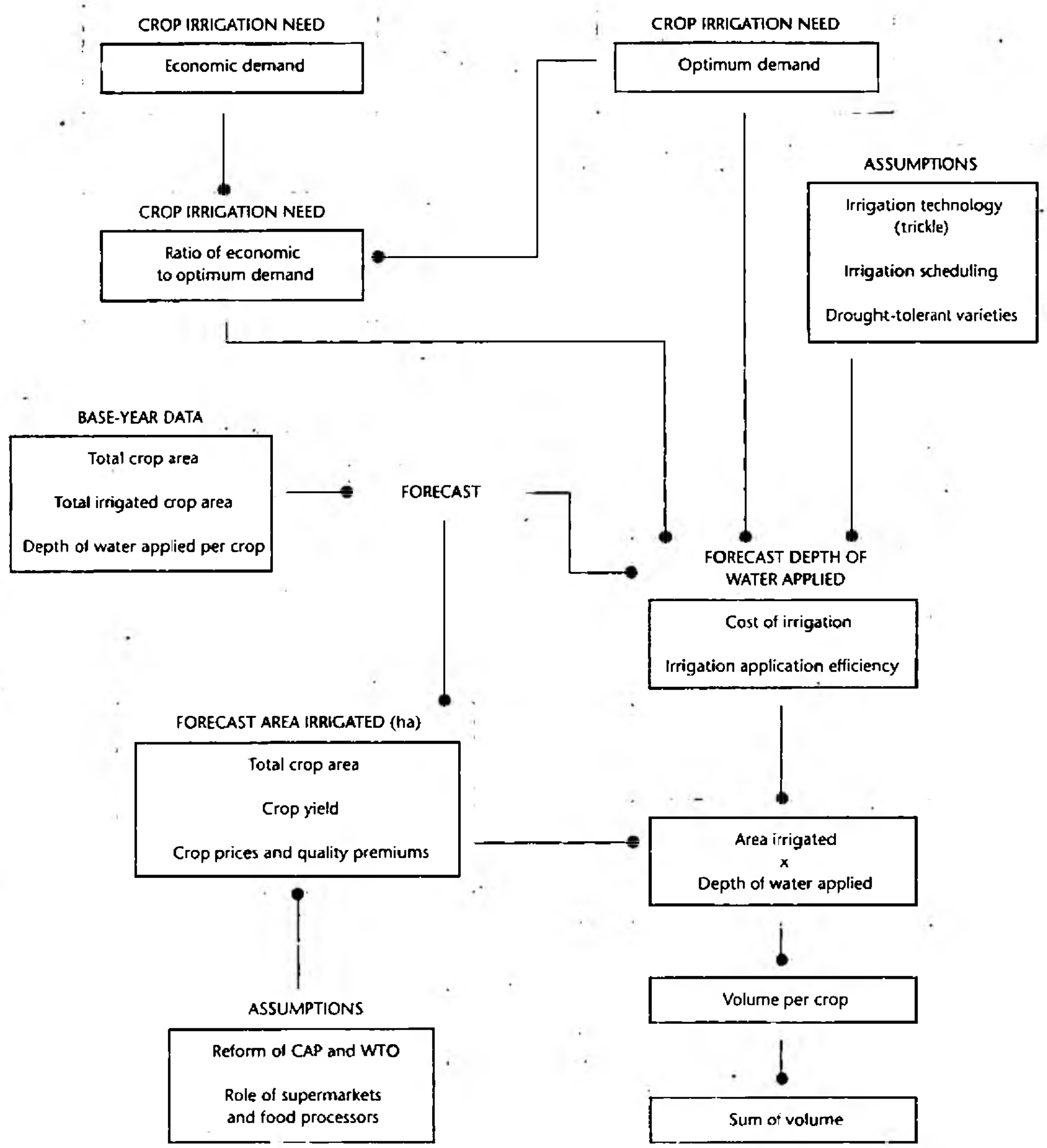
Using the 1995 MAFF irrigation survey has a number of limitations. The most important of these is the timelag; it is seven years since the last survey. Our forecasts will not capture recent changes in the pattern of production of irrigated crops across England and Wales, or reflect recent trends in the use of equipment and scheduling systems. As a consequence, the forecasts potentially under- or over-estimate the extent of irrigation in some regions.

The second critical issue is the scale at which MAFF data are reported. To prevent disclosure of individual farm information, the survey results are reported at county level. Although a method has been applied to aggregate this information to Agency regional boundaries, it is impossible to represent accurately the spatial distribution of spray irrigation within a region. It is therefore difficult to reconcile demand against available water resources. Future irrigation surveys should ensure that forecast-results can be presented at smaller geographical units such as hydrometric areas, large catchments or sub-catchments, or relate to agro-climatic zones.

7.2.2 Future land use data

One of the main drivers of spray irrigation demand is the allocation of land to each crop and the proportion irrigated. The area irrigated is calculated within our forecast model; land-use data, broken down by crop type, represents an input value. Predictions of future land use and crop areas are produced by organisations such as MAFF and a number of universities. They have

Figure 7.3 **Key stages in the spray irrigation forecast process**



developed their own agronomic models to predict the effects of policy reforms implemented through CAP and WTO. Land-use models have also been developed as part of the REGIS and IMPEL research projects to consider future changes in crop area. For our purposes these forecasts are of limited utility; they do not consider the same crop categories as our spray irrigation model. For example, potato and sugar beet crops are explicitly considered in the models developed by MAFF, but soft fruit, orchard fruit and vegetable are not. Although these crops make up a small proportion of total land area, they represent a large proportion of the total irrigated area. Spray irrigation forecasts are particularly sensitive to changes in the total area of these crops and robust future predictions are important.

To address this issue we have drawn on forecasts of crop area, yield and price developed by Weatherhead et al (1994), specifically related to our irrigation crop categories. This information was calculated using the Manchester University Agricultural Policy model (Burton, 1992). These values have been updated as a baseline scenario. They reflect the continued reform of the CAP under the WTO regime, whereby levels of agricultural support are reduced, farm commodity prices move towards world market levels, and approximately 15 percent of the 1992 cropped area is taken out of production. We have used this baseline scenario information as a reference point to develop scenario-specific growth factors.

Table 7.2 Link between the key drivers and micro-components of spray irrigation demand

Driver of demand	Area irrigated (ha)			Depth of water applied (mm)			
	Crop area	Crop yield	Crop price	Optimum irrigation need	Ratio of economic to optimum need	Irrigation efficiency	Cost of irrigation
CAP and GATT/WTO reform	✓		✓				
Sourcing polices of supermarkets and food processing firms	✓		✓		✓	✓	
Changing pattern of potato production	✓	✓	✓		✓		
Changing pattern of sugar beet production	✓	✓	✓		✓		
Drought tolerant cropping varieties	✓	✓	✓	✓	✓		✓
Irrigation management and scheduling		✓	✓		✓	✓	✓
Irrigation equipment, e.g. trickle irrigation					✓	✓	✓
Winter storage reservoirs							✓

7.3

Forecast scenario assumptions

Table 3.3 reports our assessment of the effects of the four scenarios on the key drivers of spray irrigation demand. This provides the framework for the development, by scenario, of crop-specific assumptions related to the seven micro-components of spray irrigation demand. Table 7.2 shows the linkages between the different micro-components and drivers of spray irrigation demand.

Although we have identified each micro-component as an independent variable, in reality there is a very close relationship between crop area, yield and price. Three principles of agricultural economic underpin the development of our scenario-specific assumptions:

- increases in the supply of a crop, through high yields, will affect its selling price. If yields are high due to improvements in productive efficiency, the market may be oversupplied, depressing the market price. Hence high crop yields do not sustain high crop prices;
- in the season(s) following a period of market over-supply, the crop area may reduce as farmers attempt to minimise their financial risks;
- there are natural limits on the availability of land and its suitability for certain types of production, due to soil type and agro-climatic conditions. In addition, rotational restrictions prevent crops being grown on the same piece of land continuously.

The scenario-specific assumptions and growth factors are set out in Appendix 16.

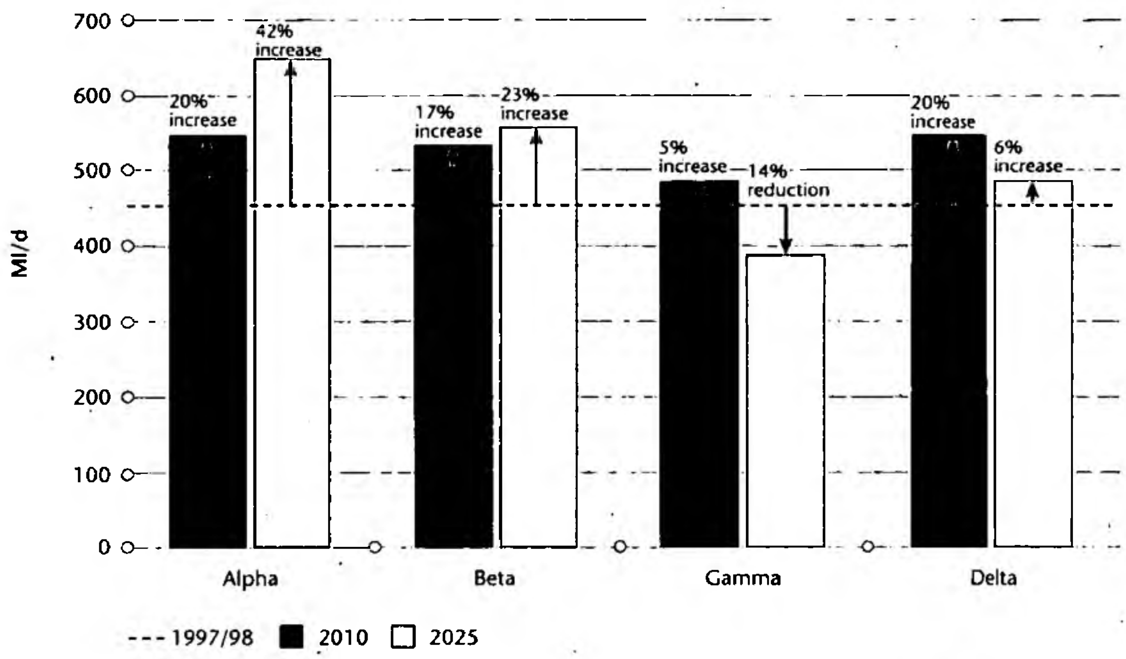
7.4

Climate change and crop irrigation requirement

Climate change will have an effect on agriculture. It will affect not only planting and harvesting dates, but also the varieties of crop grown and their distribution across England and Wales. Climate change may allow an extension of the area given to crops that are presently marginal, such as lupins, sunflowers and navy beans. In combination, these changes will influence crop water requirements and irrigation need.

To help us estimate the potential impact of climate change on current optimum irrigation needs, we commissioned Cranfield University at Silsoe to develop and apply a new methodology. This builds on the concept of agro-climatic zones, and calculates optimum irrigation need values for each crop category under the four climate change scenarios published in 1998 (Hulme and Jenkins, 1998). Regional monthly climate change factors (Arnell, 1999) for each of the four core UKCIP scenarios were applied to the daily long-term (20-year) weather data sets of six weather stations

Figure 7.4 Spray irrigation, by scenario in 2010 and 2025



across England and Wales. The location of these weather stations are representative of the agro-climatic zones. For each station rainfall and potential evapo-transpiration values were generated for each of the UKCIP climate change scenarios. These values were input into the irrigation water requirements model developed at Cranfield University by Hess (1996) to generate revised annual irrigation needs for eight crop categories.

Analysis of the data indicates that, for the eight categories studied, optimum irrigation need would increase at the six sites considered. The magnitude of the increase varies quite markedly in relation to the climate change scenario. For some early season crops, for example early potatoes, the effects of climate change lead to a relatively small increase in irrigation need; while for crops with growing seasons that extend through the summer, the potential effects on crop water requirement are more significant. These results are still only preliminary and additional work is required to improve the statistical robustness of the method. The DETR-commissioned study of the impact of climate change on water demand by the Environmental Change Institute at the University of Oxford will build on this work.

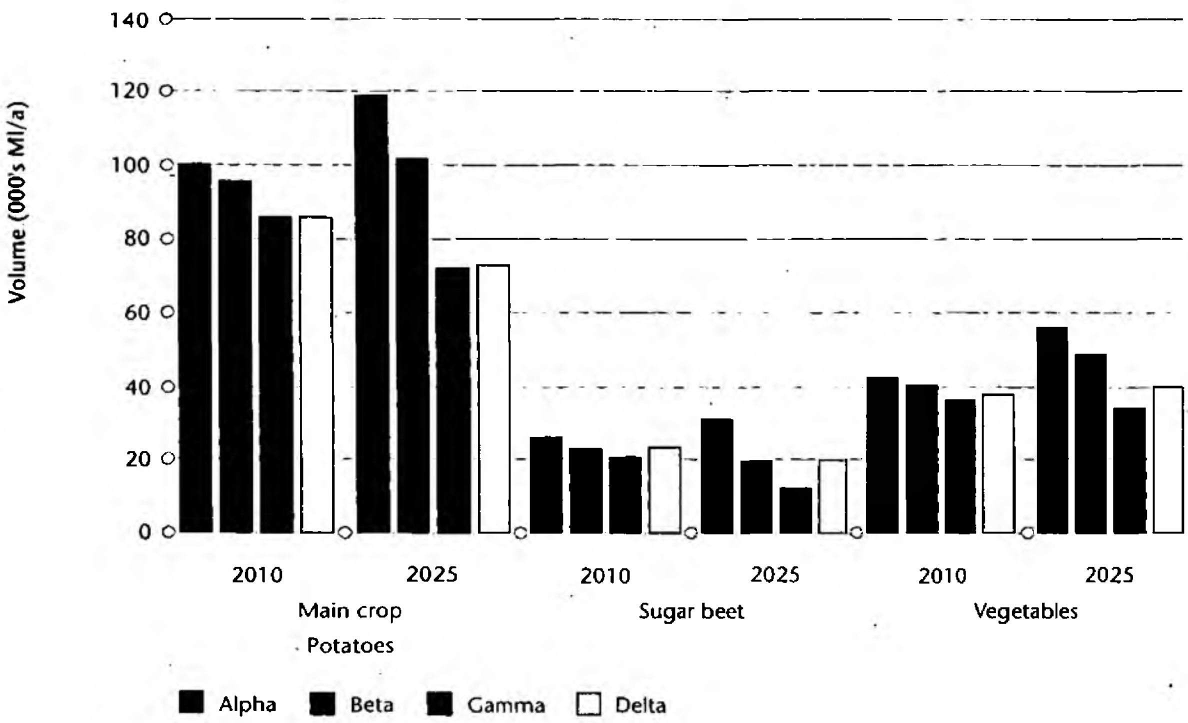
Over the next 25 years, climate change will be just one of many challenges facing agriculture. Others will include reform of the Common Agricultural Policy (CAP), increased globalisation of the market for agricultural produce, and changing consumer preferences. It is within this context that we should assess the impact of climate change on spray irrigation demand. For this reason we have not included a climate change allowance within our spray irrigation demand scenarios.

7.5 Scenario outcomes

Figures 7.4 and 7.5 illustrate the effect of each scenario on total spray irrigation demand, excluding climate change. Compared to our current position, by 2010 the changes in demand are quite small. By 2025 there are marked differences, with two scenarios seeing an increase in demand while two decrease. In each scenario the factors leading to these changes are different. In this section we summarise how the changes in social values and systems of governance in each scenario impact on the drivers of spray irrigation demand.

Scenario Alpha: Government adopts a protectionist approach, introducing trade barriers to protect UK markets and producers. A modified CAP applies, supporting and protecting a relatively intensive, regionally focused agriculture. There is a strong emphasis on home produce and self-sufficiency, with a reduction in the level of food imports. This serves to increase the total area of crops such as potatoes, sugar beet, and field-scale vegetables, although as yields gradually increase the total area under production

Figure 7.5 National volume of water applied to main irrigated crops, by scenario in 2010 and 2025



declines slightly by 2025. Supermarkets and food processing firms continue to focus on produce quality with associated high price premiums. The proportion of high-value crops such as potatoes and vegetables increases by 2025. The price premiums encourage greater efficiency in the use of irrigation, although technological innovation in irrigation equipment and scheduling systems is limited.

Scenario Beta: Agriculture becomes increasingly concentrated, industrialised and driven by global markets. The CAP is abandoned; European farm commodity prices fall, although world prices themselves rise marginally. UK agriculture is subject to strong international competition with the level of food imports increasing. This particularly affects potato, sugar beet and orchard fruit crops, where total area declines. Despite this, the emphasis on produce quality, and the associated high price premiums, favour increased irrigation of high-value speciality potato and horticultural crops. The proportion of these crops that are irrigated steadily increases by 2025.

Scenario Gamma: The CAP is subject to fundamental reform, with a switch to agri-environmental support schemes. The level of food imports increase; with a consequent reduction in the total areas of potatoes, sugar beet and orchard fruit. Supermarkets revise their approach to agriculture, using their influence to promote and support environmentally sensitive systems of production. Price premiums for irrigated produce fall, as consumers place less emphasis on the appearance of produce. This, combined with the widespread adoption of drought-tolerant varieties, encourages farmers to reduce the depth of water applied. Irrigation efficiencies increase rapidly, reflecting government investment in the development of irrigation technology.

Scenario Delta: The CAP is replaced by national and regional agricultural policies. Significant emphasis is placed on food self-sufficiency, with a movement away from reliance on supermarkets to local shops and farmers' markets. Produce appearance becomes less important, reducing the incentive to irrigate. The area under organic or low-input systems increases, with a consequent increase in total crop areas. For crops such as potatoes and vegetables, the total area increases by 2025. Average yields reduce, average farm commodity prices rise and input costs fall. Water is used wisely because of its associated public good, rather than its cost, leading to high irrigation efficiencies.

8 The total water demand scenarios

In preceding chapters we set out the methods and assumptions we have applied to develop scenario-based demand forecasts. For each component we have assessed the consequences of changes in social values and systems of goverance.

In this chapter, we draw together this information to assess the overall effects on total water demand..This chapter has six sections. Section 8.1 considers the broad implications of each scenario on total demand at two time steps: 2010 and 2025. At the aggregate level, total water demand for each scenario masks important variations in the behaviour of each component. In Sections 8.2 to 8.5 we consider these issues through a combination of qualitative story line and quantitative indicators to demonstrate the factors influencing our water demand scenarios. Each section starts with a summary of the high-level Foresight scenario characteristics.

Figures 8.1 and 8.2 display the scenario effects on total demand in 2010 and 2025 for England and Wales. Regional and water company figures are reported in Appendix 17.

8.1 Aggregate total water demand – 2010 and 2025

Many of the changes implied within the scenarios do not become apparent in the forecasts until after 2010. Until this date the changes in total demand are small. In contrast, by 2025 there are quite large differences between scenarios (Figure 8.3). The largest increase is within Scenario Alpha, with a 53 percent growth in total demand by 2025. This is largely accounted for by the step increase in leakage. A more moderate rate of growth is experienced in Scenario Beta, with total demand increasing by 7 percent. Scenarios Gamma and Delta both show marked reductions in demand of 40 percent and 34 percent respectively. Although the magnitude of these reductions is broadly similar, the factors leading to these changes are quite different.

These national figures mask some of the important regional and sub-regional differences. The differential rates of growth in component demand will reflect the industrial and economic geography of England and Wales. Some uses of water are concentrated in particular regions. For example, spray irrigation mainly takes place in the Anglian and Midlands Regions so their total demand will be particularly sensitive to changes in this component. The pattern of industrial development in England and Wales means that some regions are more sensitive to changes in one sector of industry or commerce. For example, changes to the chemicals industry will have a major impact in North West Region, while demand within Midlands Region will prove sensitive to changes in the engineering sector.

The consequences of changes in social values and systems of governance for the use and management of water vary by component. The processes of deregulation, realignment of economic and political policy priorities, and changes in social attitudes will have a variable impact on the different drivers of component demand. The water policy drivers will prove particularly sensitive to changes in the system of governance, while technological drivers will be influenced by broader changes in the level of economic growth and attitude towards capital investment projects. In the following sections, we set out the water demand scenario story lines and quantitative demand indicators to demonstrate the linkages between the different components, and the variable influence of the scenarios on the drivers of component demand.

Figure 8.1 Aggregate total water demand for England and Wales in 2010 and 2025

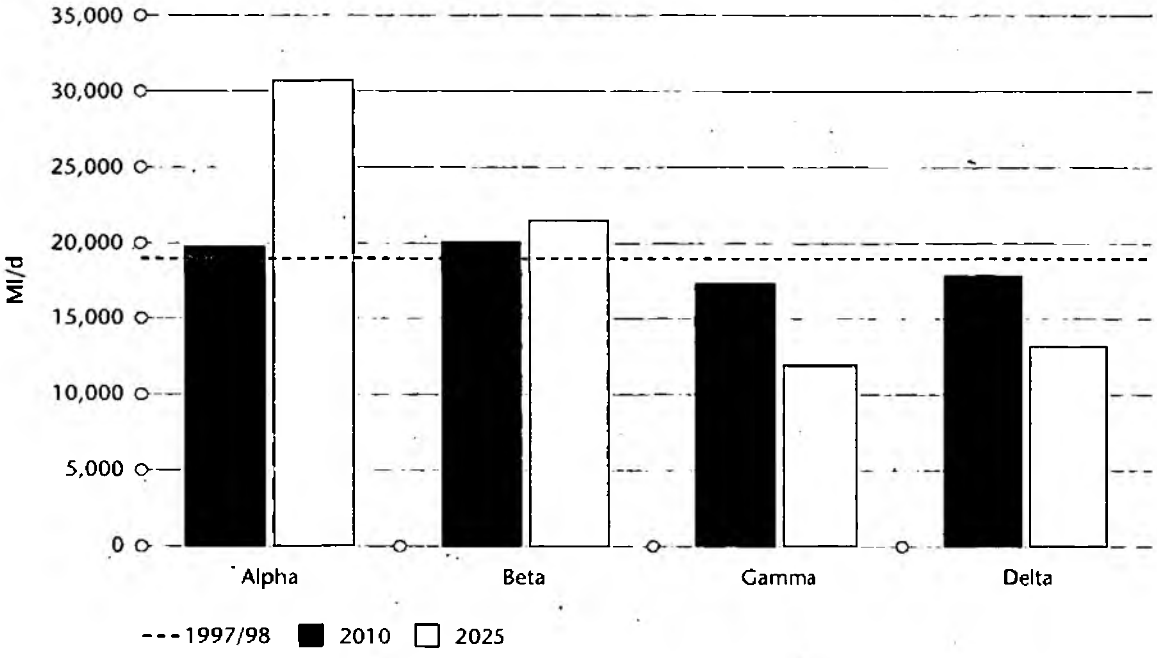
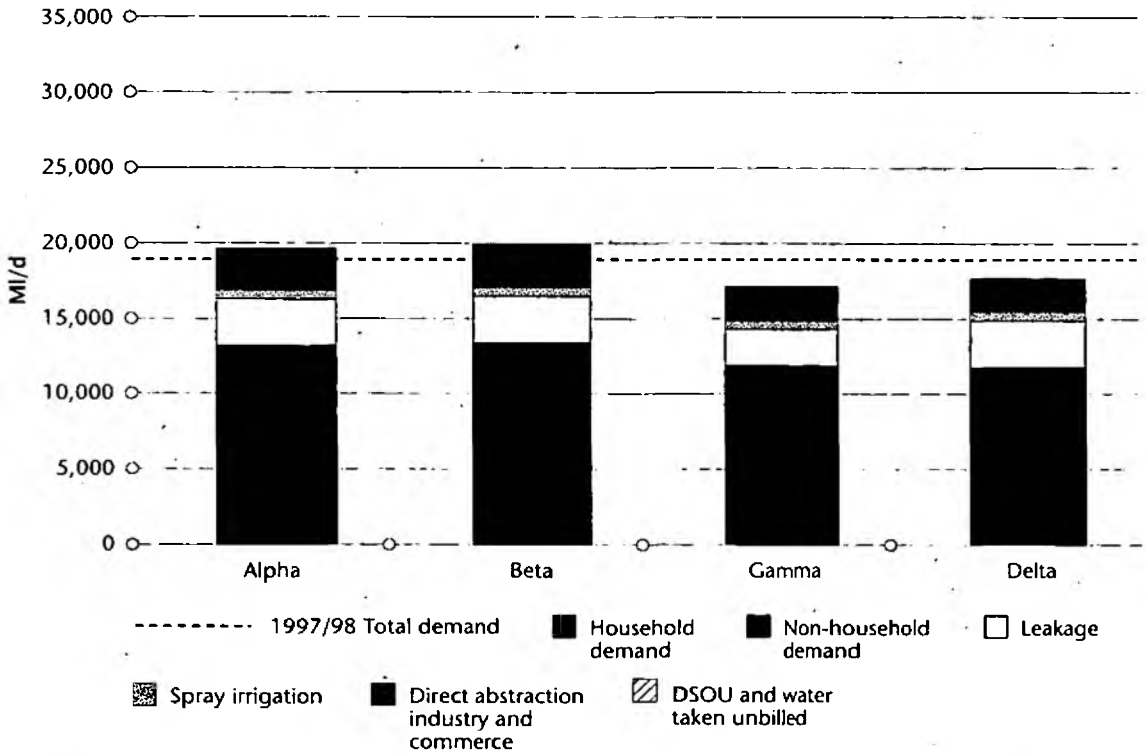


Figure 8.2 Total demand for England and Wales, by component in 2010



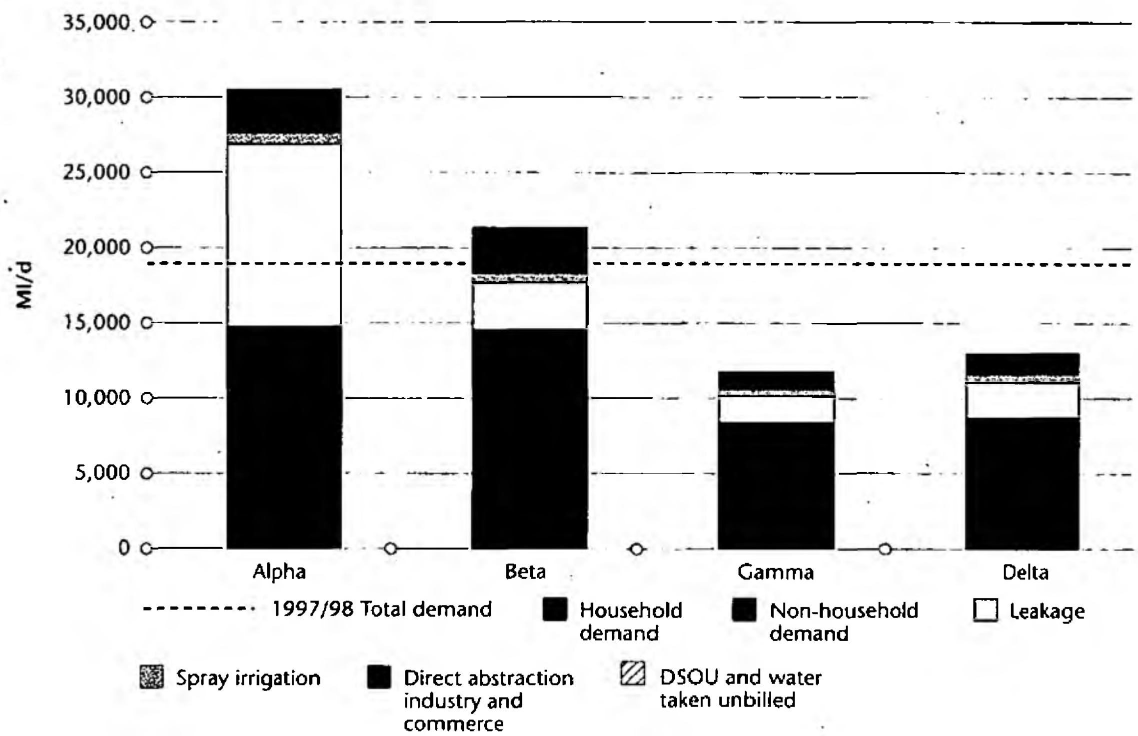
8.2

Scenario Alpha

The nation state disengages from international systems of economic and political regulation. This is a low-growth, low-investment scenario in which short termism predominates. Sustainable development and the environment are low-priority issues and do not feature in the decision-making frameworks of politicians, policy makers, businesses, farmers or householders.

Deregulation of the public water supply leads to major reform of the framework governing the operation of

Figure 8.3 Total demand for England and Wales, by component in 2025



water companies in England and Wales. The system of water company regulation is weakened, with little incentive for investment in leakage control and household water metering. The system of setting leakage targets is withdrawn. By 2025 lack of investment results in **leakage levels increasing** at the natural rate of rise, so that **leakage makes up 40 percent of total demand.** Deregulation also limits investment in household metering to areas in the south and east considered water scarce. In other parts of the country, metering is a low-priority issue, reflecting the public's ambivalence towards the environment. By 2025 **the number of metered households does not exceed 25 percent in areas outside the south and east of England.**

Withdrawal from international economic and political systems of regulation results in the realignment of economic policy priorities. In industry, commerce and agriculture the level of imports and exports declines, with production realigned to meet domestic demand. The long-term decline in some high-water-using industries such as metals, textiles and engineering is reversed, while other low-water-using sectors go into decline. This, coupled with the low level of uptake of water-use minimisation measures, means that for **public water supply, industrial and commercial, demand for water increases by 13 percent in 2025 and 15 percent for industries using direct abstraction.** In agriculture, production is realigned so that a larger proportion of produce is sourced in the UK. This, coupled with the continued price premium for high-quality produce, results in an **increase in spray irrigation demand of 42 percent in 2025.**

This low-growth scenario inhibits investment, with limited research and development in new technologies. This critically influences all the demand components. In the household sector this means that the development of more water-efficient white goods is curtailed. In industry and commerce, water-use minimisation activity is limited to options that incur no capital costs, while the development of more efficient spray irrigation application equipment is stifled.

The level of personal affluence declines in this scenario, which discourages the replacement of water-using appliances as well as the purchase of new water-using devices. In combination this results in a low level of penetration of water-efficient appliances within the home. As a result by 2025 **total national household demand has increased by** an average of **33 percent.**

8.3

Scenario Beta

A highly developed and integrated world trading system generates high levels of economic growth. Although *personal affluence rises, there is little concern for social equity. Awareness and concern for the environment is low, particularly among the less well off.*

National systems of economic and political regulation are reformed and repealed to ensure the effective operation of international trading regimes. The water industry is subject to light levels of state regulation with government and the regulators playing a minor role in determining investment in leakage control and household metering. Given the primacy of market forces of regulation, politicians and policy makers assume that competition will result in the efficient operation of water companies and therefore leakage targets are relaxed. **Leakage levels therefore remain fairly stable at the current level to 2025.** The growing importance of competition in the water industry means that metering of households is seen as critical. This, coupled with the low level of political concern for social equity, means that **by 2015 virtually all households are metered.**

With the gradual removal of all national and international trade barriers, industry, commerce and agriculture have to compete at world prices without any subsidies from the state. In industry and commerce this accelerates the decline of primary manufacturing sectors, with UK businesses unable to compete with the low-wage economies of the Far East and Eastern Europe. This decline is balanced by the high rates of growth experienced in the service and high-technology sectors. This restructuring of the UK industrial base results in a shift to less water-intensive systems of production. Combined with the high level of economic growth, this results in **demand for water in industry and commerce from public water supply increasing by 34 percent in 2025.** In contrast, the decline in primary manufacturing results in a slower rate of growth in **direct abstraction demand of 19 percent in 2025.** In agriculture, strong international competition leads to an increase in the level of imports of some fruit and vegetable produce. This results in a reduction in total crop area and irrigated area. However, produce grown in the UK is subject to stricter quality controls by supermarkets and food processing firms, and consequently the depth of water applied increases. Overall this results in **a 23 percent increase in spray irrigation demand.**

This is a high-growth scenario with high levels of investment. Technological innovations are quickly transferred across the globe. This leads to rapid improvements in the water efficiency of white goods. Within industry, commerce and agriculture the drive to technological innovation results in the uptake of low-cost water-use minimisation measures and the development of more efficient and effective application equipment and scheduling systems for spray irrigation.

High levels of personal affluence encourage the rapid replacement of water-using appliances with more water-efficient systems. This is counterbalanced by the purchase of new, high-water-using equipment such as pressure washers, garden watering equipment and other discretionary uses such as swimming pools. This culminates in **an increase in household demand of 19 percent by 2025.**

8.4

Scenario Gamma

Global institutions play a central role resolving social and environmental problems. High levels of investment in research and development result in the development of innovative clean technologies that benefit the environment.

With government placing the environment at the heart of all decision making, the water industry is subject to strong regulation. High levels of government investment result in the rapid transfer of technological innovations. The regulatory system governing the water industry facilitates this process, through leakage targets and regulation. Leakage targets reflect innovative technical solutions that result in a **57 percent reduction in leakage by 2025.** Water regulations are revised, to introduce stricter legal limits on the water flow and volume limits of all water-using devices and appliances – this is particularly important for high discretionary uses such as power showers. This facilitates innovation and the development of highly efficient water-using devices and appliances. These changes play a critical role and **household demand for water declines by 28 percent in 2025.** Resource-intensive systems of industrial and agricultural production are also subject to stricter environmental regulation. In agriculture this is reflected in the reform of the Common Agricultural Policy (CAP), and in industry the introduction of regulations on water-use minimisation. This culminates in a **decline in industrial and commercial demand for water of 29 percent from public water supply and 54 percent from direct abstraction by 2025.**

Over time these reforms will facilitate changes in the way the environment is valued by society. Hence water will play a larger role in the decision making of individuals, farmers and businesses. Many will introduce voluntary measures to make the most effective and efficient use of their water. In the household this will be reflected in the purchase of water-efficient appliances, in industry and commerce through the incorporation of water-use minimisation measures within supplier contracts, and in agriculture changes to crop and land management practices. Changes to the on-farm management of irrigation water coupled with the realignment of the supermarket quality specifications results in a **decline in spray irrigation demand of 14 percent by 2025.**

8.5

Scenario Delta

Dominated by regional and local systems of government. Working at the local level, environmental problems are resolved through collective action.

Given the decentralisation of decision making to regional and local organisations, the system of regulation of the water industry becomes fragmented. Despite this, the environment is at the centre of all decision making and leakage targets are set to reflect political rather than economic priorities. Hence leakage levels are set at a uniform level of 10 percent of distribution input for all water companies in England and Wales, which culminates in a **decline in leakage levels of 41 percent by 2025.**

Production within industry, commerce and agriculture is realigned to meet the needs of local and regional customers. National and international trade in goods and services is inhibited, resulting in a restructuring of businesses away from large multinational companies to small and medium-sized enterprises. There is a movement away from reliance on supermarkets to local shops and farmers' markets. Reflecting the shift in political and economic priorities, some high-water-using industrial sectors go into decline. The high priority placed on the environment means that most businesses quickly implement voluntary measures. This culminates in **a decline in industry and commercial water demand of 36 percent of public water supply and 45 percent of direct abstraction**. The use and management of water within the home changes quite markedly, as householders instigate simple changes in their behaviour. There is a decline in discretionary water uses such as garden watering, and new high-water-using appliances and equipment are not favoured. This culminates in a **decline in household demand of 20 percent by 2025**.

Agriculture is subject to major restructuring, with greater emphasis placed on self-sufficiency in food. There is a switch to organic and low-input systems of production that results in an increase in the area under production, and consequently an increase in the area irrigated. **By 2025 spray irrigation demand increases by 6 percent.**

8.6

Summary

Our use of the Foresight framework is carefully formulated so that the resulting water demand scenarios cover the most likely pattern of water use. This does not mean that they are inevitable; these patterns represent the reaction of people, industry and agriculture to a set of social and governmental values and priorities. The combination of factors leading to each scenario is only one way that these results could arise. The development of society and government systems is complex, and our scenarios represent only four possible snapshots of the future. It is most likely that the future will follow some other path, combining some factors from each of our scenarios, and some aspects that we have not considered.

Each scenario sets out the consequences of different combinations of social, political, economic and technological change for the use and management of water. Understanding how these factors influence the drivers of component demand makes it easier to identify the type and scale of water resource management measure(s) that may be required. In our water resources strategy for England and Wales we set out how we have used the demand scenarios, and the decision-making framework that we have applied to assess the combination of resource management, demand management and resource development measures that may be appropriate in different regions and water companies in the future.

9 Conclusions and recommendations

Together with assessments of resource availability and the water needs of the environment, the water demand scenarios are key building blocks in the development of our water resources strategies. Only by combining these elements is it possible to identify the actions necessary to manage water resources over the next 25 years. The principles underpinning this process are set out in the national water resources strategy, along with the proposed solutions, to ensure that supply meets demand through all four scenarios. The regional strategies report the detailed assessments.

In this final chapter we return to the objectives set out in Chapter 1, and confine our conclusions and recommendations to technical questions related to the development of scenario-based component forecasts. The chapter is divided into three sections. Section 9.1 focuses on the role of socio-economic scenarios in forecasting the demand for water. The analysis assesses the advantages of such an approach in developing a water resources strategy. In Section 9.2 we review the methods employed in the development of component forecasts against the objectives set in Chapter 1. The final section sets out our recommendations, which are intended to inform debate in the field of water demand forecasting.

9.1 Socio-economic scenarios and forecasting the demand for water

Forecasts of water demand are developed for a number of distinct purposes within water resources planning. Water companies develop forecasts for submission to the Environment Agency and Ofwat as part of their business planning process. These propose and justify water resource management options for incorporation into Ofwat's periodic review of water charges. Water companies make decisions about the way they want to manage their supply-demand balance according to the values of the company and their understanding of the needs of their customers. The forecasts developed as part of this process are currently reviewed every five years. Our strategic forecasts adopt a broader perspective, and reflect our vision for the long-term management of water resources throughout England and Wales. These water resources planning initiatives have different purposes which influence the type of forecasts developed, which in turn determine how scenarios are used within the forecasting process.

Scenarios are often used to address the risks and uncertainties inherent in forecasting, by assessing the sensitivity of a forecast to changes in key components. The use of scenarios within water resources planning is not new. The 1994 water resources strategy *Water: Nature's precious resource* (NRA, 1994) described three scenarios. These scenarios demonstrated the effects of different levels of demand growth, as well as the role of leakage control activity and metering policies in managing water resources in England and Wales. These scenarios adopted a limited perspective, however, and did not consider explicitly the social, economic or political factors that might bring about these different levels of metering and leakage control.

One of the major elements of uncertainty in forecasting water demand is predicting how society will respond to future economic, political or technological change. We acknowledge that such changes will have direct and indirect consequences for the use and management of water. However, some elements of water use are more certain than others. For example, some water-using appliances are subject to control through the Water Supply (Water Fittings) Regulations, which provide volumetric limits such as maximum toilet flush. Traditionally, the greatest area of uncertainty relates to the behavioural elements of water use. Individual discretion will influence the number of times an individual will bath or shower in a week, the length of time spent in the shower, or the propensity to water the lawn. Such behavioural elements are difficult to predict as an individual's values, relative affluence and lifestyle are critical influences.

Our use of scenarios marks an important departure as they allow us to address explicitly these issues. The Foresight "Environmental Futures" framework allows us to consider four possible future societies and to track the effects of different combinations of social values and systems of governance on the use and management of water. By understanding the factors driving demand under each scenario, we can develop an approach that involves managing water use and expectations to produce a strategy that is robust and flexible.

9.2 Forecast methods

In applying a scenario-based approach to water demand we have demonstrated the importance of component and micro-component-based forecasts. By considering the sensitivity of each micro-component to the different drivers of demand we have been able to link water demand to the foresight "Environmental Futures" framework. We have assumed that the drivers of demand remain constant across all four scenarios. This means that we have been able to develop a single forecasting model for each component of demand to which we apply scenario-specific assumptions. Such an approach enables us to illustrate and quantify the impact of different combinations of social values and systems of governance on future water use.

The forecast methods that we have employed are all in line with water industry "best practice" (UKWIR/NRA, 1995; UKWIR/Agency 1997). To forecast household demand we have applied a micro-component method, while the forecasts of industrial and commercial demand adopt a weighted output growth approach. The approach to leakage is consistent with that recommended in *Managing water leakage: economic and technical issues* (Lambert *et al*, 1998) and *Managing Leakage* (UK Water Industry, 1994). For our spray irrigation forecasts we have built on the results of two Agency research and development projects, to develop a new approach linked to the concept of economic demand.

To inform the development of our scenario-based assumptions we have undertaken extensive literature reviews and consulted a number of organisations (Appendix 18). The technologies and policies included within the four scenarios are all available within the UK or overseas today. Hence the assumptions are within present bounds of possibility and represent a realistic assessment of likely change. Within each scenario, the assumptions regarding social, economic, technological and political change across the different components are consistent with the Foresight framework. We have applied our assumptions consistently across England and Wales.

9.2.1 Component-based forecasts

Household

At the time of our analysis, micro-component data were available from eight water companies in England and Wales. These companies account for about 47 percent of the national population and are spread across England and Wales. We have assigned each resource zone in England and Wales to one of the micro-component templates. This established a nationally consistent data set, from which we projected unmeasured and measured per capita consumption for each of the 125 resource zones in England and Wales.

To each micro-component we have applied scenario-specific assumptions to each element of ownership, frequency of use and volume. These assumptions are consistent nationally. In the case of garden watering, we have considered the influence of life style characteristics and regional location on the ownership of different types of garden watering equipment.

In developing assumptions to account for the effect of metering on demand, we have developed an approach in line with the recommendations of the UKWIR/Environment Agency (1997) *Forecasting water demand components: Best Practice Manual.* Rather than simply applying a single suppression factor to unmeasured per capita consumption, we have considered the effect of metering on each micro-component of household demand. In the context of the four scenarios, switching to a metered supply has both a short- and long-term effect on water-using behaviour. Over the short term, the influence of metering will be evident as a shift in the frequency and duration of use related to some micro-components. For example, the number of times the garden is watered or the length of time spent in the shower may change. Over the longer term, metering with appropriate tariffs will change attitudes. For example, when new appliances or bathrooms are purchased, people will choose water-efficient devices. This distinction underpins our development of scenario-specific suppression factors.

We have taken as our starting point the metering suppression values reported in the National Metering Trials Working Group (1993), Edwards (1996) and Pezzey and Mill (1998). These reported values have been broken down into suppression factors related to each micro-component. As additional data and information become available we will review this approach. For example, the "Disaggregated savings due to metering" research project in Dee Valley Water will inform our approach.

Leakage

Our four leakage scenarios reflect differential approaches to setting leakage targets. Three scenarios reflect recent UK and overseas experiences, and draw on information from the recent past to inform the development of water company leakage targets. Only Scenario Gamma has necessitated detailed modelling.

Using the Bursts and Background Estimates (BABE) model, we have applied existing technology and methods, as well as changes that are already widely anticipated in the water industry to quantify the effect of best-practice leakage control policies. We have assumed that methods some companies find cost-effective today will probably be cost-effective for all water companies in the future. The BABE model is sufficiently flexible to allow us to consider a number of ways in which different leakage control methods can be implemented. This allowed us to calculate the resulting level of leakage for each water company.

The BABE modelling approach relies heavily on input data. In some cases, information is not publicly available at water company level, and we have applied default values. Future analyses would be improved by the use of specific data from water companies. In the case of pressure management, we have applied a GIS technique to generate future AZNP target values for all water companies in England and Wales. This provides a more robust method of assessment. One of the key drivers of leakage in the BABE model is the rate of bursts. Improvements in the accuracy of these data would be essential for future analyses.

In Scenario Alpha, we see increasing leakage. The rate of rise may look extreme. This is a warning that effort in leakage management must be maintained; without measurement, control and targeted activity, leakage could start to rise. It is important to note that this leakage scenario would result from a completely different set of values from those held at present. We are not suggesting that present water companies would allow leakage to rise in this way, but this could happen if the rules and targets governing leakage were relaxed in a less regulated scenario.

The tripartite leakage study sponsored by DETR, the Environment Agency and Ofwat will explore possible future approaches to leakage target setting. The assumptions developed in this forecasting work should prove useful material for this study, which will clarify the potential for progress on leakage.

Industry and commerce

The forecasts of industrial and commercial demand represent the first nationally consistent assessment of sectoral demand for water from direct abstraction and public water supply sources. Our modelling approach breaks down water consumption into different sectors, linked to the Standard Industrial Classification (SIC 92). This enables us to fully explore the effects of economic growth and changes in the structure of the economy on the demand for water. The forecasts also explicitly consider water-use minimisation measures and the effects of differential rates of uptake of such measures by SMEs and large firms. This approach allows us to consider the barriers to uptake of water-use minimisation measures and hence provide a more robust assessment of the scale of potential reductions in water use.

In developing our forecast model, we have identified two areas that would benefit from greater consistency in collating and reporting information. The first relates to water-use minimisation. We still do not know how many businesses have adopted water-use minimisation measures. A number of organisations are involved at the national, regional and local level in facilitating and encouraging businesses to adopt appropriate water-use minimisation measures. Although the results of these initiatives are widely reported, it is vital that the information is collated and reported in a standard format. This should include both the financial and water-use figures before and after implementation. The second issue relates to the use of Office of National Statistics (ONS) data within water demand forecasting. The boundaries of the Environment Agency and water companies are not standard reporting units used by ONS and hence we encountered a number of data suppression problems. This represents a source of uncertainty within our forecast model.

Spray irrigation

Our spray irrigation forecasts have developed the concept of economic demand, reflecting the costs and benefits of irrigating different crops. The approach marks an important development. Comparison of forecasts based on economic and optimum demand confirms the importance of irrigating high-value crops such as potatoes and vegetables. The economic benefits of irrigating lower-value crops such as cereals, grass and sugar beet are not sufficient to justify meeting the full optimum demand. Irrigation forecasts for these crops are significantly reduced. As a basis for forecasting, the economic demand concept provides a more robust method for projecting likely demand for water. Through phase three of the Agency's R&D project the *Optimum use of water for industry and agriculture: Best Practice Manual* we will develop further the concept of economic demand.

Through our analysis we have identified two information gaps that introduce a source of uncertainty within our spray irrigation forecasts. The 1995 MAFF irrigation survey represents the best available information on spray irrigation in England and Wales, providing the total crop area, irrigated area and depth of water applied. Since this survey was last implemented seven years ago, our forecasts will not capture recent trends in the pattern of production of irrigated crops across England and Wales, or the use of irrigation equipment and scheduling systems. As a consequence, the forecasts may over- or under-estimate the extent of irrigation in some regions.

The second information gap relates to the availability of long-term crop forecasts related to crops that are irrigated in England and Wales. Although MAFF and a number of universities routinely produce crop forecasts, they do not relate to smaller crops that are largely irrigated. Our spray irrigation forecast model is particularly sensitive to changes in the total area of these crops, and robust future predictions are important. No one organisation has direct responsibility, and as a number of organisations share an interest we will work with them to address these issues.

9.3

Recommendations

In our national water resources strategy we set out 30 actions necessary to secure the sustainable management of water resources over the next 25 years. This will require concerted action by a range of water users, the Government, the water industry, regulators, farmers, businesses, individuals and of course the Environment Agency. To monitor progress in delivering our vision of sustainable water resources management we will produce an annual review of the strategy. In time, as new information and research becomes available we will review the component forecasts.

Of particular relevance to the development of component-based forecasts are those actions from the strategy related to access to information (A7) and further research and development (A30).

9.3.1 Access to information

"Access to information is essential to ensure that "best practice" can be shared, and the open exchange of views promotes confidence that the management of resources is being carried out to best effect. While some progress has been made on information exchange, much water company information is not in the public arena and some is not available to the Agency. In particular, there is a need for clear information on leakage control methods and their costs, and the effectiveness of water efficiency measures".

To ensure that this process of information exchange informs the field of forecasting it is vital that data are collated and reported in a nationally agreed format. This encompasses not just data held by water companies but also that held by the Environment Agency and the Office of National Statistics. Our analysis has demonstrated the importance of developing:

- a water industry standard set of household micro-components categories which can be broken down into agreed sub-categories;
- a water industry standard breakdown of industrial and commercial demand into a standard set of sectors related to the Standard Industrial Classification (SIC 92) or some other nationally agreed approach;
- a consistent approach for recording and reporting the results of water-use minimisation initiatives in industry and commerce;
- an agreed method for obtaining data from ONS related to a consistent set of Agency and water company boundaries.

9.3.2 Further research and development

In the strategy we put forward 14 topic areas for further research and development. The Agency is committed to working with others to prioritise and take forward these research and development topics. Of the 14 research topics, eight contribute to the field of forecasting, either refining the methods used in component-based forecasts, or informing development of future assumptions:

- *"the use and economics of introducing drought-tolerant varieties and cropping systems into agriculture";*
- *"cultivation and land management techniques that improve the retention of water in soil, modifying catchment response to flood and drought";*
- *"impacts of climate change on demand for water – the DETR study (Climate change and the demand for water) will develop new methods for assessment, but these will need to be applied across England and Wales";*
- *"components of per capita consumption – more work is necessary to understand the drivers of individual components of water use";*
- *"garden watering – to help predict how and when gardeners will use water";*
- *"population projections – a source of uncertainty, with different organisations working with different information, a working group on population projections would help the water resources planning process";*
- *"impact of price and tariffs on domestic and industrial demand – more development work would help our understanding";*
- *"the evaluation of costs and water savings of demand management options".*

The scenario-based component forecasts form an integral element of the national and regional water resources strategies. These documents are available from our head office in Bristol or regional offices across England and Wales. If you have any specific comments or queries related to the development of the demand scenarios, please contact the Head of the National Water Demand Management Centre at our Worthing address.

Appendix 1
Assessment of the drivers of component demand by scenario

In some cases we have had to draw our own inferences of the impact of a particular scenario. These are highlighted in bold in the following tables:

Drivers of household demand	Scenario Alpha
Economic growth	Slow rates of economic growth and personal affluence. ***Capital investment is low and political will to improve infrastructure is lacking.***
Efficient technology – white goods	Lack of investment in R&D and new technology.
Metering	Widespread resistance to metering and lack of sympathy for those companies forced to balance through rationing and restrictions.
Water regulation	Very weak regulation of water use.

Drivers of household demand	Scenario Beta
Economic growth	High economic growth and personal affluence. ***High affluence results in an increase in discretionary water use.***
Efficient technology – white goods	Rapid technological innovation and transfer of new techniques across the globe. ***Affluent households desire latest technology leading to rapid replacement of white goods.***
Metering	Metering is widespread by 2010 and subsequently global. ***Increases in social inequality results in wide variation in the response of different groups.***
Water regulation	Very light regulation of utility markets. ***Role of Ofwat limited.***

Drivers of household demand	Scenario Gamma
Economic growth	Strong economic growth.
Efficient technology – white goods	High levels of investment in R&D and new technology. Emphasis on low consumption technology. ***Wide availability of water saving technology. Decline in popularity and demand for high-volume appliances such as garden watering equipment and power showers.***
Metering	Metering almost global by 2020.
Water regulation	Strong role for government. Intervention to promote "best practice" in water use.

Drivers of household demand	Scenario Delta
Economic growth	Low levels of economic growth.
Efficient technology – white goods	Investment in technologies and initiatives that have a longer payback, but long-term benefits.
Metering	***Metering and tariffs for water use have limited effect on demand. Demand reduced through increased awareness and concern for the environment and changing attitudes to the environment.***
Water regulation	Conservationist and community-based culture supports political aims of sustainable water management.

Scenario	Drivers of leakage	
Provincial enterprise	Regulatory framework	• Very weak regulation • Low levels of investment in the water industry leads to higher leakage levels • Sustainability disappears as a political objective
	Resource situation	• Low priority placed on preservation of natural assets
World markets	Regulatory framework	• Very light regulation of water utility • Market-led economy perpetuates predict and provide
	Resource situation	• Generally less concern with the environment
Global sustainability	Regulatory framework	• Strong regulation of the water industry
	Resource situation	• Global consensus on need for sustainable development
Local stewardship	Regulatory framework	• Regulation, infrastructure investments and changing social behaviour used to preserve and enhance the natural environment • Aggressive campaigns to reduce leakage
	Resource situation	• Water resources managed locally and consciousness of water efficiency increases

Drivers of industrial and commercial demand	Provincial enterprise
Trends in economic development	GDP growth at 1.5% pa. Economic growth constrained due to capital and resource shortages.
Trends in structure of economy: Manufacturing	General stabilisation in manufacturing, with growth in some areas where local production substitutes for goods previously imported. Slow change in industrial structure because traditional industries are protected from international competition. Increase in parts of manufacturing industry and defence related industries.
Service	Increase in private health, education and social services. Decline in sectors producing specialised products (eg media) operating in global markets, banking and finance.
Leisure	
SMEs	SMEs producing goods and services for the national market are the most innovative players.
Water-use minimisation: Greening of business initiatives	Industry NOT eco-efficient. Environmental investments tend to be for remediation and end of pipe technologies, driven by local environmental concerns eg air quality. Lack of investment in clean technologies in manufacturing leads to an increase in demand for water.
Waste minimisation	Use of raw materials and resources relatively inefficient.
Technological innovation	Pace of technological change slow. Most effort devoted to the refurbishment and incremental improvement of existing plant. Low level of technological innovation generally, due to low investment in R&D. Rapid uptake of technologies suited to economic smaller scale production in chemicals, paper and steel technologies enabling reuse and recycling.

Drivers of industrial and commercial demand	World markets
Trends in economic development	GDP growth 3% pa.
Trends in structure of economy: Manufacturing	Traditional manufacturing/primary industry declines. Growth in Pharmaceuticals, benefit from increase in private health care. Resource extraction grows to meet energy and infrastructure construction needs.
Service	Increase in private health care, personal care, banking and finance, distribution and transport.
Leisure	Entertainment/leisure increases.
SMEs	
Water-use minimisation: Greening of business initiatives	International "best practice" in technology and management quickly adopted. Global standards emerge for many goods and services. But lax environmental standards.
Waste minimisation	Use of materials and resources becomes more efficient with waste minimisation and eco-efficiency leading to high pay-back opportunities by 2010.
Technological innovation	Improves resource use efficiency in most sectors, but at a slow rate of 1-2% pa.

Drivers of industrial and commercial demand	Global sustainability
Trends in economic development	GDP growth at 2% pa.
Trends in structure of economy: Manufacturing	Manufacturing industry transformed by combination of high investment, and drive towards a low-input "small footprint" economy. Innovation concentrated on radical improvements in eco-efficiency across the board. Highest growth in sectors producing eco-efficient goods and services. High investment levels associated with restructuring and/or phasing out inefficient and dirty industries. Decline in resource intensive manufacturing, with increasing emphasis on provision of services rather than goods.
Service	Increase in IT, communications and integrated household service providers.
Leisure	
SMEs	
Water-use minimisation: Greening of business initiatives	Pervasive greening of business initiatives, which are highly successful. Development of external environmental regulations and development by industry/business of internal environmental management systems, which drive significant gains in resource efficiency and waste minimisation.
Waste minimisation	Rapid penetration of waste minimisation across all sectors. Resource use efficiency drives environmental policy.
Technological innovation	BAT rapidly adopted with strong partnerships between government and industry. Strong technical growth, with innovation orientated towards clean, low input production and consumption techniques.

Drivers of industrial and commercial demand	Local stewardship
Trends in economic development	GDP growth at 1% pa.
Trends in structure of economy: Manufacturing	Lower rates of investment and innovation in manufacturing industry. Major changes in industrial structure as scale of markets restricted. SMEs and technologies adapted to small scale sustainable production favoured. Slow turnover of capital but new industrial processes tend to be modular and apply principles of "process intensification" as a response to smaller markets and tight environmental controls. Supply chain relationships extended. Firms tied to local markets. Small scale manufacturing fast growing sector.
Service	Decline in retail.
Leisure	Decline in leisure and tourism.
SMEs	SMEs prosper.
Water-use minimisation: Greening of business initiatives	Stress on eco-efficiency, quality and durability.
Waste minimisation	Raw material use declines significantly through eco-efficiency, technical changes and beneficial developments in industrial structure.
Technological innovation	Demand management pursued aggressively.

Drivers of irrigation demand	Provincial enterprise
CAP	Modified CAP reform. Intensive style of agriculture with high dependence on fertiliser inputs. Food prices low.
GATT/WTO agreements	Ineffective WTO with increase in non-tariff and tariff barriers to trade. Less development of world markets for seasonal and high quality food inputs.
Organic production	*Low rate of increase.*
Supermarkets and food processing firms	Strong influence over farmers, reflected in requirement for uniform, high-quality produce. ***Continuation of present contract and produce quality specifications. Supermarkets differentiate themselves in the market place through promotion of British produce. Reduction in imports of fruit and veg from Europe, thereby an increase in area of these crops grown in UK.***
Changing pattern of potato production	Increase in total area of potatoes. Shift of production to virgin potato land. Increase in irrigated area, increase in quantity of water applied.
Drought tolerant cropping varieties	Low level of uptake of drought tolerant varieties, given supermarkets' continued specification of drought intolerant varieties.
Changing pattern of sugar beet production	Reduction in level of imports of sugar beet to meet UK demand. Total area increases, irrigated area increases.
Irrigation management and relative efficiency	Low rate of technological innovation and unavailability of capital precludes development of more efficient techniques.

Drivers of irrigation demand	World markets
CAP	CAP Abandoned. Lower food prices. Large-scale farming based on few varieties and widespread use of precision farming techniques.
GATT/WTO agreements	International trade promoted with an effective WTO. Removal of barriers to protection of domestic agricultural markets *impact on sugar beet, reduction in total area and % irrigated.*
Organic production	Low rate of increase.
Supermarkets and food processing firms	Dominate food market. ***Fail to recognise water as an environmental issue. Refine existing contract and produce quality specifications, which increase pressure on on-farm water resources. Continue to develop and source niche and out-of-season fruit and veg. Increase in % of high value crops irrigated; increase in quantity of water applied.***
Changing pattern of potato production	Dominance of large farms, ***significant reduction in number of small family farms producing potatoes. Overall a small reduction in total of area potatoes, due to reduction in world price. Acceleration of the process of concentration.***
Drought tolerant cropping varieties	***Drought tolerant GMOs developed late in the planning period.***
Changing pattern of sugar beet production	***Significant reduction in area grown in the UK due to reduction in world price with removal of trade barriers.***
Irrigation management and relative efficiency	Uptake of low cost irrigation management measures only. Innovation depends on the economics of irrigation and level of perceived market growth.

Drivers of irrigation demand	Global sustainability
CAP	Reformed CAP, switch in support from production to subsidies for environmental and landscape protection. Decline in resource intensive agri. Attempt to balance high agri yields with low environmental impacts. Widespread adoption of ICM (integrated crop management).
GATT/WTO agreements	Reformed WTO to reflect environmental and social equity considerations. Promote development of sustainable agricultural practices through taxes on inputs such as fertilisers, pesticides and herbicides.
Organic production	Moderate rate of increase.
Supermarkets and food processing firms	Strong influences over farmers transmit consumers environmental concerns via quality specifications. Supermarkets recognise water as an environmental issue – revise their produce quality specifications, and stipulate irrigation/water efficiency measures in contracts.
Changing pattern of potato production	Large scale farming declines. Potato production moves from soil types with low moisture retentive capacity. Reduction in irrigated volume; reduction in irrigated area.
Drought tolerant cropping varieties	Rapid uptake of new drought tolerant varieties which are favoured by supermarkets in their contract and quality specifications. Significant reduction in irrigated area of cereal, grass and sugar beet; significant reduction in quantity of water applied to potatoes, salad crops, root crops, soft fruit and top fruit.
Changing pattern of sugar beet production	Large scale farming declines. Reduction in number of large producers of sugar beet. Reduction in quantity of water applied.
Irrigation management and relative efficiency	High rate of uptake of efficiency measures, with development of innovative techniques.

Drivers of irrigation demand	Local stewardship
CAP	CAP withdrawn with shift to national agriculture support system and heavy subsidies to protect food security and local landscapes. Local self-sufficiency main goal of policy, and the use of traditional agricultural practices ***labour intensive.***
GATT/WTO agreements	Ineffective WTO.
Organic production	Dominant mode of production.
Supermarkets and food processing firms	Emphasis on local supplies, decline in exotic and out-of-season produce. Decline in market share of supermarkets, increase in farmers markets. Consumers are willing to accept less than "perfect produce" as they no longer define produce quality in terms of appearance. Reduction in quantity of water applied. Reduction in irrigated area.
Changing pattern of potato production	Dominance of small family farms, growing potatoes for local markets. ***Total area increases due to reduction in level of imports from Europe and yield decline (due to low level of inputs). No increase in quantity of water applied or irrigated area.***
Drought tolerant cropping varieties	Widespread use of traditional/established varieties with high drought tolerance. Reduction in irrigated area and quantity of water applied.
Changing pattern of sugar beet production	Dominance of small family farms. ***Increase in total area of sugar beet, no reduction in irrigated area or quantity of water applied.***
Irrigation management and relative efficiency	High level of government technical support allows rapid uptake of alternative production techniques. ***Widespread use of labour intensive soil management techniques, which improve moisture-retentive capacity – mulching, tillage methods, weed suppression result in a reduction in the area requiring irrigation.***

Appendix 2
Derivation of garden watering per capita consumption

Of the 14 micro-components listed in Table 4.1, the primary drivers for variation in pcc relate to socio-economic profile and level of affluence. The garden watering micro-component has the additional drivers of climate and the resource zone housing stock. For example, in the wetter west of the country, garden watering is less of an issue than in the drier east; while an area comprised mainly of flats is unlikely to have a high proportion of garden sprinkler owners. This is highlighted by the variation in pcc values between adjacent resource zones.

It would be unreasonable to apply the garden watering micro-component from the nine templates without considering these additional drivers, and so we have developed our own approach.

The ACORN system developed by CACI provides socio-economic data for 55 types, 17 groups and six categories. At the type level, CACI provide a commentary on a number of different areas of lifestyle such as housing type and leisure pursuits based on the results of the 1991 census and market research. This includes gardening. From this information we were able to establish a propensity to water the garden. This was based on the proportion of households within a resource zone that have a garden and the proportion likely to have an interest in gardening. When combined with ownership, frequency and volume per application, information taken from Herrington (1996) and consultation with manufacturers such as Hozelock, this created resource zone-specific garden-watering OFV data for the base-year.

This approach gave a reasonable match when compared with national and water company figures. For example, Hozelock estimate that some 14 percent of the population own a garden sprinkler whereas our work gave a figure of 15 percent. Similarly, while our analysis gives an ownership of other garden-watering appliances of 70 percent for Three Valleys Water's largest resource zone, the company's own estimate is 75 percent.

Appendix 3
Micro-component forecast assumption tables

WC			
Water use micro-component	**Water use factor**	**Source information**	**Micro-component assumption (shading denotes assumption is common to all scenarios)**
Standard frequency for all WC types		Herrington, 1991	Increase in WC-density results in an increase in flush frequency at an equivalent rate to 4.12 in 1996 and 4.3 in 2021.
Full flush WC (9l)	Ownership	Herrington, 1996	Water byelaws introduced in 1993 result in decline from 75% due to new properties and a replacement rate of 1 in 20 years (Scenario Gamma); 1 in 30 years (Scenario Beta); 1 in 40 years (Scenario Alpha and Scenario Delta).
	Volume	Herrington, 1996	Flush volume constant at 9l.
Dual flush WC (7.5l)	Ownership	Herrington, 1996	Water byelaws introduced in 1993 rule out a dual flush in new houses, therefore ownership remains constant at 25% until 2001. Water Regulations (1999) lowers maximum flush to 6l which results in a decline from 2001 onwards from 25% due to new properties and a replacement rate of 1 in 20 years (Scenario Gamma); 1 in 30 years (Scenario Beta); 1 in 40 years (Scenario Alpha and Scenario Delta)
	Volume	Herrington, 1996	Flush volume constant at 7.5l.
Low volume WC (7l)	Ownership		Represented as a residual allowing for combined full flush and dual flush ownership until 2001. Water Regulations (1999) result in no more of these units being installed from 2001. Thereafter ownership declines due to new properties and a replacement rate of 1 in 20 years (Scenario Gamma); 1 in 30 years (Scenario Beta); 1 in 40 years (Scenario Alpha and Scenario Delta).
	Volume	Herrington, 1996	Flush volume constant at 7l.
Dual flush WC (4.5l)	Ownership		Increase of 1% per year from 2001 in all scenarios reflecting increase in housing stock at a similar rate and assuming a steady rate of installation in existing housing stock. No demand from 2010 in Scenario Beta and Scenario Alpha as regulations are relaxed, replacement rate thereafter of 1 in 30 years (Scenario Beta); 1 in 40 years (Scenario Alpha). New regulations in Scenario Gamma require a maximum flush of 4l from 2015, replacement rate thereafter of 1 in 20 years. Similarly in Scenario Delta, although a new lower dual flush and some composting toilets also available, replacement rate thereafter of 1 in 40 years.
	Volume		Flush volume constant at 6l:4l with a flush ratio of 1:3 = 4.5l average volume
Low volume WC (6l)	Ownership		Represented as a residual from 2001 onwards in Scenario Beta and Scenario Alpha allowing for combined full flush, dual flush (7.5l and 4.5l) and low volume WC (7l) ownership. Similarly in Scenario Gamma and Scenario Delta, although installation ceases from 2015 and replacement rate thereafter of 1 in 20 years (Scenario Gamma) due to new regulation; 1 in 40 years (Scenario Delta) due to desire to minimise water consumption and willingness to adopt alternative technologies.
	Volume		Flush volume constant at 6l.
Future technology	Ownership		Not applicable in Scenario Beta or Scenario Alpha. New regulation in Scenario Gamma applicable from 2015 results in decline of all other types of WC, to be replaced with 4l low volume flush WC. In Scenario Delta a dual flush WC is also available from 2015 and ownership is assumed to be in equal proportions, as ownership of all other types of WC declines. Introduction of composting toilets in Scenario Delta from 2015 is slow but assumed to reach 2% by 2025.
	Volume		Flush volume constant at 4l in Scenario Gamma. The average flush volume is constant at 3.25l in Scenario Delta (Assuming a 4l low flush and 2.5l dual flush WC; based on 4l and 2l flushes with a flushing ratio of 1:3).

Personal washing			
Water use micro-component	**Water use factor**	**Source information**	**Micro-component assumption (shading denotes assumption is common to all scenarios)**
Bath	Ownership	Herrington, 1996	Rate of decline consistent with ownership of 97% in 1991 and 91% in 2021 for the whole period. Minimum ownership set at 85%.
	Frequency		Rate of decline consistent with frequency of 0.34/h/d in 1991 and 0.31/h/d in 2021. Decrease is as a result of the increasing preference for showering.
	Volume		Bath volume constant.
Standard shower	Ownership	Herrington, 1996	In Scenario Beta and Scenario Alpha the growth of standard showers is calculated as a residual of overall shower ownership in 2025 (96%) less power shower ownership. In Scenario Gamma and Scenario Delta the rate of growth, until 2010, is consistent with overall shower ownership (power and standard) of 50% in 1997/98 and 96% in 2025. From 2010 regulations dispense with high volume power showers. Growth rate is increased as existing power showers are either adapted to restrict flow or are replaced with lower volume showers at rates of 1 in 20 years in Scenario Gamma; 1 in 15 in Scenario Delta where regulations are more readily applied.
	Frequency	Herrington, 1996	Rate of increase consistent with frequency of 0.35/h/d in 1991 and 0.5/h/d in 2021 to a maximum of 0.6/h/d.
	Volume		Shower volume constant.
Power shower	Ownership	Herrington, 1996 BRE, 1999.	A recent BRE shower manufacturer's survey of home building individuals states 84% choose power shower as most important feature when selecting a shower. To remove some of the sample bias and accepting this would represent an upper estimate of ownership in Scenario Beta by 2025, the figure is reduced 59% – used as a cap to growth. In Scenario Alpha the ownership is estimated to not exceed 50% by 2025. In Scenario Gamma and Scenario Delta the growth rate until 2010 is equivalent to 5% in 1991 and 50% in 2021. Thereafter ownership declines as units are replaced or modified in response to regulations which limit the flow. Rates of decline are 1 in 20 years in Scenario Gamma; 1 in 15 in Scenario Delta where regulations are more readily applied.
	Frequency	Herrington, 1996	In Scenario Beta, Scenario Alpha and Scenario Gamma frequency increases at a rate equivalent to 0.52/h/d in 1991 and 0.6/h/d in 2021 to a maximum of 0.61/h/d, to reflect higher use rate for power showers. However, for those resource zones with a base-year frequency greater than 0.61/h/d, hold frequency constant throughout planning period. In Scenario Delta the frequency does not exceed 0.57/h/d; equivalent to the frequency for 2010 assuming a similar rate of growth as for the other scenarios.
	Volume		From manufacturers' product specifications/brochures, maximum shower volumes could be as much as 150l. This might equate to 10-min duration and 15l/min flow rate. Average volumes are currently under 100l therefore this assumption might represent an upper limit for 2025 in Scenario Beta and Scenario Alpha. In Scenario Gamma and Scenario Delta the volumes remain constant throughout the forecast.
Hand basin	Pcc		Remains constant throughout the period.

Clothes washing			
Water use micro-component	**Water use factor**	**Source information**	**Micro-component assumption (shading denotes assumption is common to all scenarios)**
Automatic washing machines	Ownership	ONS, In Figures. OECU, '99 (DECADE)	base-year cross checked to General Household Survey information and washing machine growth limited to a saturation of 94% by 2010. From 2015 onwards in Scenario Delta, increase in community based projects, eg laundrettes and communal washing services, leads to a reduction in individual ownership of 0.5% /year.
	Frequency	Herrington, 1996	In Scenario Beta, Scenario Alpha and Scenario Gamma frequency decreases at a rate equivalent to 4.5/H/w in 1991 and 4.3/H/w in 2021. This reflects continued decline in household size. As this trend is halted and potentially reversed in Scenario Delta the frequency is held constant from 2015 onwards.
	Volume		The rate of reduction in volume reflecting technological developments varies across scenarios such that in Scenario Beta volume reduces to 50l by 2025; in Scenario Alpha volume reduces to 80l by 2010 (continuing current trends) and remains constant thereafter; in Scenario Gamma and Scenario Delta rate of decline increases from that seen in Scenario Beta from 2010 to an average volume of 40l by 2025.
Washing by hand	Ownership		Calculated as the residual of those households who do not use a washing machine.
	Pcc		Growth dependent on the change in ownership. Frequency and volume assumed to remain constant throughout period.

Dish washing			
Dishwasher	Ownership	Herrington, 1996. ONS Regional Trends 34, 1999	Data from ONS suggests ownership of 22% in 1997/98. Assuming the average to be 20% in 1991 gives an annual growth rate of 1.7%/year which is maintained in the Gamma scenario. In Scenario Beta, the higher economic growth might accelerate the rate of uptake to about 2%/year. From 2010, in Scenario Alpha, growth rate assumed to reduce to 1.5%/year reflecting the slower economic growth. In Scenario Delta the environmental /conservationist ethic, coupled with slow economic growth results in a growth rate of 1%/year.
	Frequency		Remains constant throughout the period.
	Volume		The rate of reduction in volume reflecting technological developments varies across scenarios such that in Scenario Beta volume reduces to 20l by 2025; in Scenario Alpha volume reduces to 30l by 2010 and remains constant thereafter; in Scenario Gamma and Scenario Delta volume reduction accelerates from 2010 to reach 15l by 2025 assisted by greater investment in clean and environment-friendly technologies and sustainable policies.
Washing-up by hand	Ownership		Calculated as the residual of those households who do not use an automatic dishwasher.
	Frequency		Remains constant throughout the period.
	Volume		Remains constant throughout the period.

Garden watering			
Water use micro-component	**Water use factor**	**Source information**	**Micro-component assumption (shading denotes assumption is common to all scenarios)**
Garden sprinkler	Ownership	Herrington, 1996, CACI: ACORN, General Household Survey, HTA, Hozelock	The 25% of households, nationally, who enjoy gardening are assumed to own a sprinkler. Gives an average of 15% sprinkler ownership in 1997/98 taking account of ACORN household information. The resource zone-specific ownership increases, in Scenario Beta, at a rate of 0.5%/yr to a maximum of 29% by 2025 (based on DoE) for SE companies and a maximum of 20% for all other companies. A slower rate of growth is assumed in Scenario Alpha, 0.25%/year from 2010. Ownership is assumed to remain constant from 2010 in Scenario Gamma and reduce in Scenario Delta to 7.5% in the south east and 5% elsewhere.
	Frequency	Herrington, 1996	In Scenario Beta and Scenario Alpha frequency increases at a rate equivalent to 20/Hhld/year in 1991 and 25/Hhld/year in 2021. From 2010 frequency remains constant in Scenario Gamma, and halves in Scenario Delta to reflect only essential usage.
	Volume		Remains constant throughout the period.
Other garden watering	Ownership	Herrington, 1996, CACI: ACORN General Household Survey	Assumed that 90% of those households with a propensity for gardening as classified by ACORN type use something other than a sprinkler to water their garden. Gives a national average of 54% in 1997/98. The resource zone-specific ownership increases at 0.5%/yr to a max of 70% by 2025 (based on Herrington, 1996) for SE companies and remains constant elsewhere.
	Frequency	Herrington, 1996	In Scenario Beta and Scenario Alpha frequency increases at a rate equivalent to 39/Hhld/year in 1991 and 58/Hhld/year in 2021. From 2010 frequency remains constant in Scenario Gamma, and halves in Scenario Delta to reflect only essential usage.
	Volume	Herrington, 1996	In all scenarios volume per use increases at a rate equivalent to 132l in 1991 and 153l in 2021. From 2010, in Scenario Delta, the volume per use decreases by half by 2025 to reflect only essential usage.

Car washing			
Hose and bucket	pcc	Herrington, 1996	Combining the Herrington, 1996 assumptions, pcc increases at a rate equivalent to 0.9l/h/d in 1991 and 1.5 l/h/d in 2021 in Scenario Beta and Scenario Alpha. In Scenario Gamma, the pcc remains constant through the period. In Scenario Delta, the pcc declines with car use to 0.5 l/h/d.

Direct heating system			
Combination boilers	Ownership	BISRIA, 2000	13% for 2000 with an annual growth of 0.5 million units/year. From 2015, in Scenario Gamma and Scenario Delta, incorporation of a pre-heating device removes the need to run off cold and tepid water thus ownership remains constant thereafter.
	Frequency	pers comm.	5/Hhld/d (10/Hhld/d for 6 mths of the year). Remains constant throughout the period.
	Volume	pers comm.	5l. Remains constant throughout the period.

Miscellaneous			
Miscellaneous	Volume		Growth in miscellaneous use reflects the average combined growth of all the other micro-components for the relevant scenario.

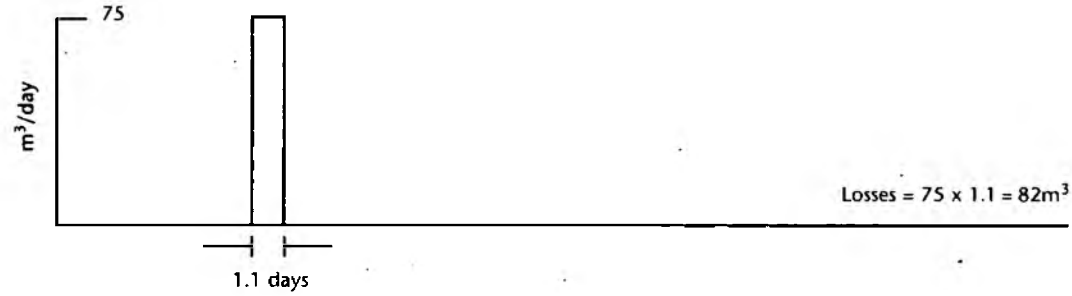
Appendix 4
Assumptions used in BABE modelling

- Flow rates from bursts (default values in BABE model).
- The estimation of supply pipe and communication pipe bursts = 5 per 1,000 service connections/year and then split 60:40 comm:supply pipe (Lambert et al (1999)).
- The ratio of reported to unreported bursts: 95 per cent reported assumed on trunk mains, 75 percent on distribution mains, 50 percent for communication pipes and supply pipes. Note that these are different to Lambert et al , where 98 percent, 95 percent, and 75 percent reported are assumed respectively, for international systems. The higher proportions of unreported bursts in England and Wales are intended to reflect the higher degree of ALC that takes place and is based on earlier estimates.
- For all companies the number of supply pipes = 0.9 x number of properties.
- The effect of modelling pressure reduction is confined to reducing the leakage flow out of existing holes and cracks, where leakage from bursts is proportional to the square root of the pressure and from background leakage is proportional to the power of 1.5 of the pressure. There has been no attempt to model the relationship between pressure reduction and burst frequency due to limited existing data. As a result the modelled savings from pressure reduction are likely to be conservative.
- The initial background losses are 40 l/km/hr for distribution mains, 3 l/prop/hr for communication pipes and 1 l/prop/hr for supply pipes (UK Water Industry (1994)).
- In the modelling only the effect of improved background leakage is considered, as services and mains replacement is implemented. The likely reduction in burst rate has not been considered.

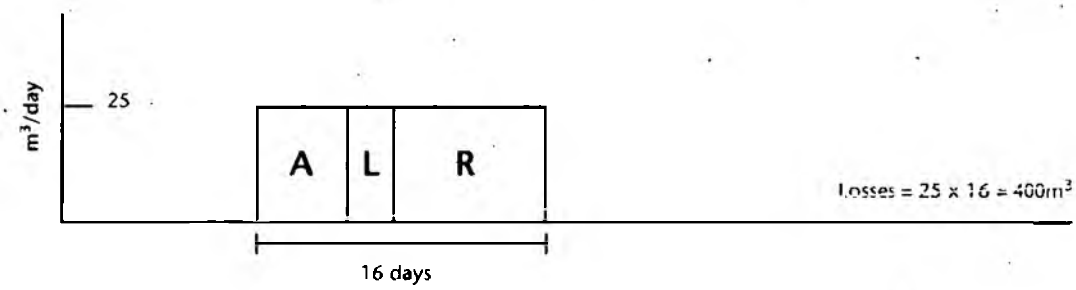
Appendix 5

Awareness, location, repair (ALR) for mains, communication and supply pipes

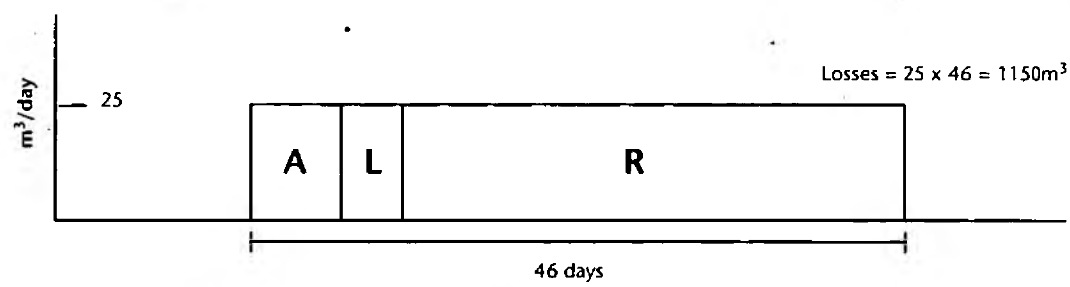
Mains burst



Communication burst



Supply pipe burst



A = Awareness L = Location R = Repair

Effect of duration on reported bursts – 40m AZNP

The above examples demonstrate that it is not necessarily the largest bursts that make the greatest contributions to the leakage level. While the rate of water loss is high, because it will be noticed and reported by the public the location time will be short, as will be the repair time because it will be accorded a high priority. The communication and supply pipe bursts leak more slowly but lose more water because they have longer run times. Supply pipes often presented a particular problem because it was the customer's responsibility to effect the repair, under pressure to do so from the water company. This has been less of an issue since the "ten-point-plan" after which most companies offered to repair supply pipes free of charge.

Appendix 6

Water company categorisation by relief variability

The divisions were chosen to give the following classifications:

Flat	Mixed	Hilly
York	South Staffs	South West
Tendring Hundred	South East	Northumbrian
Essex and Suffolk	Southern	Dŵr Cymru
Cambridge	Mid Kent	Yorkshire
North Surrey	Sutton and East Surrey	
Bournemouth and West Hants	Thames	
Three Valleys	Wessex	
Anglian	Bristol	
Hartlepool	Folkestone and Dover	
Portsmouth	Severn Trent	
	North West	
	Dee Valley	

Company categorisation by relief

Two adjustments have been made to the results of this exercise: North West and Dee Valley have been placed in the "mixed" category rather than hilly (as per the height index), since the population centres are situated largely in flat areas.

Appendix 7

Background loss rates

Distribution mains

Starting background loss	40	l/km/hr	Target background loss	20	l/km/hr	
Res Cat	**Repl rate**	**2005**	**2010**	**2015**	**2020**	**2025**
1	3%	37	34	31	28	25
2	2%	38	36	34	32	30
3	1%	39	38	37	36	35

Communication pipes

Starting background loss	3	l/prop/hr	Target background loss	1.5	l/prop/hr	
Res Cat	**Repl rate**	**2005**	**2010**	**2015**	**2020**	**2025**
1	3%	2.775	2.55	2.325	2.1	1.875
2	2%	2.85	2.7	2.55	2.4	2.25
3	1%	2.925	2.85	2.775	2.7	2.625

Supply pipes

Starting background loss	1	l/prop/hr	Target background loss	0.5	l/prop/hr	
Res Cat	**Repl rate**	**2005**	**2010**	**2015**	**2020**	**2025**
1	3%	0.925	0.85	0.775	0.7	0.625
2	2%	0.95	0.9	0.85	0.8	0.75
3	1%	0.975	0.95	0.925	0.9	0.875

Appendix 8

Resource categorisation

The resource categories have been allocated by evaluating surplus (by comparing distribution input (98/99) with water available for use (WAFU)) and expressing it as percent WAFU. Category 1 is <10 percent, category 2 is 10 percent <20 percent and category 3 is >20 percent. There has been one "pragmatic" adjustment: Bournemouth and West Hants have been moved from resource category 3 to 2 due to the peak demand issue (weekly and monthly as opposed to consideration of daily), recognising that leakage control can play a role in alleviating the problems.

Resource category 1	Resource category 2	Resource category 3
Folkestone and Dover	Dŵr Cymru	Hartlepool
Thames	Three Valleys	Portsmouth
Wessex	North Surrey	York
North West	Anglian	Tendring
Dee Valley	Mid Kent	Sutton and East Surrey
South East	Southern	Northumbrian
Severn Trent	Cambridge	
Bristol	Essex and Suffolk	
South West	South Staffs	
	Yorkshire	
	Bournemouth and W. Hants	

This table does not recognise that within water companies there can be considerable variations in percentage surplus in different water resource zones, but for reasons of data availability we have not been able to carry out the modelling at a water resource zone level.

Appendix 9

Leakage forecasting in water resource zones

Due to lack of specific data on water resource zones on a number of important leakage parameters such as AZNP and burst rates, it was not possible to carry out meaningful calculations of leakage at this level. Because the forecasts were carried out at water resource zone (WRZ) level, we adopted the following approach to disaggregate leakage from water company to WRZ level.

The starting point is the leakage in the base-year, at WRZ level from WRP submissions. The apportionment of company-level leakage reduction over a given period needs to consider both the initial level of leakage in each resource zone and the number of properties in each zone. It is too simplistic to assume that the greatest scope for reducing leakage rests in zones with the highest leakage level in the base-year. The reduction factor used to derive the resource zone-specific leakage from the company figure was calculated in two stages as follows:

$$RZ(i)LRatio = \frac{RZ(i)L_{(Ini)}}{WCL_{(Ini)}}$$

$$RZ(i)RFactor = \frac{RZ(i)L_{Ratio} \times RZ(i)P}{\sum_{i=1}^{n} (RZ(i)L_{Ratio} \times RZ(i)P)}$$

where,

n	=	Number of resoure zones
$RZ(i)L_{Ratio}$	=	Resource zone leakage ratio
$RZ(i)L_{(Ini)}$	=	Base-year resource zone leakage (Ml/d)
$WCL_{(Ini)}$	=	Base-year water company leakage (Ml/d)
RZ(i)RFactor	=	Resource zone leakage reduction factor
RZ(i)P	=	Resource zone property numbers

These equations combine to normalise for the differences in property distribution across a water company. They allowed us to apportion the company-level leakage reduction, from BABE, in relation to each resource zone's initial level of leakage.

Appendix 10

Water minimisation hierarchy and associated water reduction by sector

	Industrial Sectors															
	Extraction	Utilities	Fuel	Chemicals	Minerals	Metals	Machinery	Electrical Equipment	Transport	Food & Drink	Textiles	Wood	Paper	Rubber	Construction	Other
Good housekeeping	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	31%	20%	20%	20%	20%	20%
Management	15%	20%	20%	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Good housekeeping & management	15%	30%	30%	30%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Reuse	50%	10%	10%	10%	50%	50%	50%	50%	50%	50%	15%	50%	50%	50%	50%	50%
Recycling	60%	10%	10%	10%	60%	60%	60%	60%	60%	60%	15%	60%	60%	60%	60%	60%
Redesign	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	25%	10%	10%	10%	10%	10%
Source	ETBBP GG67; ETBBP GG152	ETBBP NC55	Hill, 1995	Hill, 1995	ETBBP GG67	ETBBP EG45	ETBBP GG67	ETBBP GG67	ETBBP GG67	ETBBP GG67	ETBBP EG98	ETBBP GG67	ETBBP GG67	ETBBP GG67	ETBBP GG67	ETBBP GG67

	Service Sectors		
	Education and health	Hotels	Offices
Good housekeeping			6%
Management			14%
Water saving technology			25%
General savings	26%	3%	
Source	Suresh Surendran, pers comm, March 2000	Suresh Surendran, pers comm, March 2000	Suresh Surendran, pers comm, March 2000

Appendix 11

Summary calculation for forecast of industrial and commercial demand

Base-year water use:

$$\alpha_{p(sb)} = \frac{NHH_{p(sb)}}{OUT_{p(sb)}}$$

$$ß_{s(sb)} = \frac{NHH_{s(sb)}}{EMP_{s(sb)}}$$

Where:

$\alpha_{p(sb)}$ = average water used per unit of output in production industry (p) in the base-year for a given size band

$ß_{s(sb)}$ = average water used per unit of employment in service industry (s) in the base-year for a given size band

$NHH_{p(sb)}$ = total non-household demand from production sector (p) for a given size band

$NHH_{s(sb)}$ = total non-household demand from service sector (s) for a given size band

$OUT_{p(sb)}$ = output in production industry (p) for a given size band

$EMP_{s(sb)}$ = employment in service industry (s) for a given size band

Forecast water use (for any given year):

$H\alpha_{p(sb)} = \alpha_{p(sb)} * HWES_{p(sb)}$ $M\alpha_{p(sb)} = \alpha_{p(sb)} * MWES_{p(sb)}$
$Lap_{(sb)} = \alpha_{p(sb)} * LWES_{p(sb)}$ $Hß_{s(sb)} = ß_{s(sb)} * HWES_{s(sb)}$
$Mß_{s(sb)} = ß_{s(sb)} * MWES_{s(sb)}$ $Lß_{s(sb)} = ß_{s(sb)} * LWES_{s(sb)}$

Where:

$H\alpha_{p(sb)}$ $M\alpha_{p(sb)}$ $L\alpha_{p(sb)}$ = average water used per unit of output in production industry (p) with high, medium or low water efficiency saving uptake (respectively) for a given size band

$Hß_{s(sb)}$ $Mß_{s(sb)}$ $Lß_{s(sb)}$ = average water used per unit of output in service sector (s) with high, medium or low water efficiency saving uptake (respectively) for a given size band

$HWES_{p(sb)}$ $MWES_{p(sb)}$ $LWES_{p(sb)}$ = 1 – savings achieved from a high, medium or low level of water efficiency saving uptake (respectively) for production industry (p) and a given size band

$HWES_{s(sb)}$ $MWES_{s(sb)}$ $LWES_{s(sb)}$ = 1 – savings achieved from a high, medium or low level of water efficiency-saving uptake (respectively) for service sector (s) and a given size band

Forecast water demand (for any given year):

$TNHH_{p(sb)} = [(HWEU_{p(sb)} * COUT_{p(sb)}) * H\alpha_{p(sb)}] + [(MWEU_{p(sb)} * COUT_{p(sb)}) * M\alpha_{p(sb)}] + [(LWEU_{p(sb)} * COUT_{p(sb)}) * L\alpha_{p(sb)}] + [(NWEU_{p(sb)} * COUT_{p(sb)}) * \alpha_{p(sb)}]$

$TNHH_{s(sb)} = [(HWEU_{s(sb)} * CEMP_{s(sb)}) * Hß_{s(sb)}] + [(MWEUs(sb) * CEMP_{s(sb)}) * Mß_{s(sb)}] + [(LWEU_{s(sb)} * CEMP_{s(sb)}) * Lßs_{s(sb)}] + [(NWEU_{s(sb)} * CEMP_{s(sb)}) * ß_{s(sb)}]$

Where:

$TNHH_{p(sb)}$ = total non-household water demand from production industry (p) for a given size band

$TNHH_{s(sb)}$ = total non-household water demand from service sector (s) for a given size band

$HWEU_{p(sb)}$ $MWEU_{p(sb)}$ $LWEU_{p(sb)}$ = proportion of companies within production industry (p) adopting high, medium or low water efficiency saving uptake (respectively) for a given size band

$HWEU_{s(sb)}$ $MWEU_{s(sb)}$ $LWEU_{s(sb)}$ = proportion of companies within service sector (s) adopting high, medium or low water efficiency saving uptake (respectively) for a given size band

$NWEU_{p(sb)}$ = proportion of companies within production industry (p) not adopting any water efficiency savings for a given size band

$NWEU_{s(sb)}$ = proportion of companies within service sector (s) not adopting any water efficiency savings for a given size band

$COUT_{p(sb)}$ = calculated output in production industry (p) for a given size band

$CEMP_{s(sb)}$ = calculated output in service sector (s) for a given size band

$TNHH_p = \sum TNHH_{p(sb)}$
$TNHH_s = \sum TNHH_{s(sb)}$

Where:

$TNHH_p$ = total non-household demand from production industry (p)

$TNHH_s$ = total non-household demand from service sector (s)

$TNHH = TNHH_p + TNHH_s$

Where:

TNHH = total non-household demand

Appendix 12

Data sources

Model	Data requirement	Source	Specification	Scale
Public Water Supply Model	Water consumption	Water company	1997 water use broken down by SIC (92) 2 letter category	Water company
Public Water Supply Model	Gross output (£)	ONS Annual Business Survey	1997 data broken down into 2 letter SIC (92) categories cross-tabulated into 3 size bands for – • number of businesses; • gross output (£); • number employed.	Water company
	Gross output (tonnes)	ONS Products of the European Community (PRODCOM)	1997 data £/unit of output per 2 letter SIC (92) categories	England and Wales
Public Water Supply Model	Employment	ONS Inter-departmental Business Register (PA1003)	1997 data, broken down into the 2 letter SIC (92) categories, cross tabulated into 3 size bands for – • number of businesses; • number employed.	Water company
Direct Abstraction Model	Water consumption	Agency NALD database	1997 licensed abstraction, broken down by secondary categories	Agency boundaries
Direct Abstraction Model	Gross output (£)	ONS Annual Business Survey	1997 data, broken down into SIC (92) 4 digit level, cross-tabulated into the three size bands for – • number of businesses; • gross output (£); • number employed; • purchase of water and energy for use in production.	Agency boundary
	Gross output (tonnes)	ONS Products of the European Community (PRODCOM)	1997 data £/unit of output per 4 digit SIC (92) categories	England and Wales

Appendix 13

Scenario assumptions and associated growth factors – industrial and commercial sectors

	Foresight	Impact on forecast category	Assumption
Scenario Alpha	Industry not eco-efficient. Lack of investment in manufacturing infrastructure.	All forecast categories	From 2015 assume business implement simple water efficiency measures options 1,2. No differentiation by firm size or sector. Low level of uptake of water efficiency measures the majority of firms make no changes. Thereby assume that from 2009/10 2% of firms are categorised as "high" uptake and 1% within the "medium" uptake category.
Scenario Beta	Technological innovation improves resource use efficiency in most sectors, but at a slow rate of 1-2% pa.	All forecast categories	From 2009/10 businesses implement water efficiency measures 1,2,3. By end of period assume that 20% of firms implement water efficiency measures.
Scenario Gamma	Development of external environmental regulations which drive significant resource efficiency gains.	Chemicals Food and drink Paper Refuse Rubber Metals Utilities Fuel Textiles	From 2009/10 assume 90% of businesses in these sectors will be affected by these regulations and will implement water-use minimisation measures 1,2,3,4.
	Pervasive greening of business initiatives which are highly successful.	Extraction Minerals Electrical equipment Transport Wood Construction Retail/business services Education and health Hotels Other	From 2009/10 assume 30% of businesses implement water-use minimisation measures rising to 50% by 2025. Differentiate between size band 0-99 who implement options 1,2,3; whereas those in size band 100-299, and 300+ implement options 1,2,3,4.
Scenario Delta	Raw material use declines significantly through eco-efficiency, technical changes and beneficial developments in industrial structure.	All categories	From 2009/10 assume all sectors implement water-use minimisation measures 1,2,3. Limited availability of capital prevents wide spread retrofitting and re-design of plant. Assume all businesses fall within the "high" uptake category, and that 65% of firms implement water–use minimisation measures.

Key to water-use minimisation options

Production-based industries

1. Good housekeeping
2. Management
3. Good housekeeping and management
4. Reuse
5. Recycle
6. Redesign

Service-based industries

1. Good housekeeping
2. Management
3. Good housekeeping and management
4. Water saving technology

Level of economic growth and structural changes to the economy

	Foresight	Impact on forecast category	Assumption
Scenario Alpha	GDP growth 1.5%.	All forecast categories	Adjusted by –0.5% below the baseline scenario
	Slow change in industrial structure, general stabilisation in manufacturing with decline in level of imports.	Textiles Rubber Paper Machinery	From 2009/10 stable rate of growth
	Sectors operating in global markets face slower growth rates.	Chemicals Business/services/retail Metals Transport Electrical equipment	Decline from 2009/10
	Increase in private sector health, education and social services.	Education and health	Increase from 2009/10
	Increase in food and drink, linkage to growth in spray irrigation.	Food and drink	Increase from 2009/10
Scenario Beta	GDP growth 3%	All forecast categories	Adjust the baseline scenario by +1%.
	Development of WTO – removal of trade barriers.	Minerals Textiles Rubber Metals Machinery Transport	Assume WTO reforms implemented with removal of all barriers to international trade by 2009/10 – results in decline in UK-based production of some goods.
	Growth in pharmaceuticals and bio-technology	Chemicals	Increase from 2004/05
	Resource extraction increases	Extraction Construction	Increase from 2004/05
	Increase in private health care and education, banking and finance, and leisure.	Health and education Business services Hotels	Increase from 2004/05 Increase from 2004/05 Increase from 2004/05
Scenario Gamma	GDP growth 2%	All forecast categories	In line with baseline scenario growth
	Decline in resource intensive manufacturing	Paper Minerals Rubber Textiles Metals Fuel	Decline in affected sectors from 2009/10
	Increase in IT and communications	Retail/business services	Increase from 2005
	Growth in use of bio-technology techniques	Chemicals	Increase from 2005
Scenario Delta	GDP growth 1%		Adjusted 1% below the baseline scenario
	Minor changes in industrial structure, as scale of markets is restricted. Decline in MNCs – but SMEs prosper.	All categories	Rate of growth differentiated by size of firm, decline in rate of growth for size bands 100 – 299 and 300+.
	Decline in retail	Business/services/retail	Decline from 2009/10
	Decline in leisure	Hotels	Decline from 2009/10
	Decline in chemicals and bio-technology	Chemicals	Decline from 2009/10

Appendix 14
Method for calculating the ratio of economic to optimum demand

i. Cranfield University's Irrigation Water Requirements (IWR) computer programme (Hess, 1994) was first used to estimate water use, and annual levels of water stress, over a 20-year sequence of wet and dry years for the selected crop/soil/site combinations. This was repeated for a range of equipment peak-flow capacity constraints (unlimited, 3 mm/day, 2 mm/day, 1 mm/day, nil) and annual water resource constraints (unlimited, design dry-year need, midway between dry-year and average-year need, and average-year need). The results give average-year water use, dry-year water use, and average levels of water stress.

ii. Two approaches were tested for predicting yield and quality losses due to these irrigation constraints:

(a) from the modelled level of water stress;

(b) combining modelled water use with published yield and quality responses to "depth of water usefully applied".

Although the former approach would be preferable, there is a lack of quantitative data on how stress affects marketable yield and quality. The latter approach is compatible with data produced in the "Spray irrigation cost benefit" R&D project, and has been used in this analysis.

iii. The difference (mm) between the average unconstrained demand and the average constrained demand, at the given constraint level, shows the effect of those constraints on water use.

iv. This difference is multiplied by the yield response (t/ha-mm) and deducted from maximum yield (t/ha) to calculate average yield (t/ha). The same difference is compared with the optimum demand (mm) in design dry years and the reported unirrigated dry-year quality losses for that soil type (from Morris *et al*, 1997), to calculate average quality losses and hence average price (£/t). Multiplying the average yield (t/ha) by the average price (£/t) and deducting additional harvest costs (£/ha), gives the average irrigation benefit (or rather avoidance of loss) for the given constraint level (£/ha). This methodology assumes a linear response to water usefully applied both for yield and quality. This may not be realistic for some crops, but is used in the absence of better quantitative data.

v. A very simplified partial farm economic analysis is used to calculate the annualised costs (£/ha) of providing the various system capacities and annual water resources, using alternative irrigation systems with different capacities, and either summer or winter abstraction. The methodology requires data on the costs of capital equipment, insurance, repairs, fuel, labour and water, and also reservoirs where appropriate. Relevant cost data are drawn from Weatherhead *et al* (1997).

vi. The annualised irrigation costs (£/ha) are deducted from the average annual benefit (£/ha) to determine net irrigation benefits (£/ha).

Appendix 15

Base-year data, by crop type and Agency region

Agency Region	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
North East	1,258	18,722	20,213	10	424	12,568	573,150	429,171
North West	1,617	7,995	1,782	32	246	6,990	581,184	81,617
Midlands	4,028	23,020	26,868	3,003	1,625	9,699	784,088	437,248
Anglian	7,182	45,777	142,962	4,527	2,606	70,279	296,510	981,409
Thames	397	2,343	1,212	709	847	3,278	224,971	257,345
Southern	1,876	3,869	61	12,663	2,748	7,786	247,603	190,594
South West	2,471	6,217	712	1,661	767	3,815	983,009	248,133
Welsh	2,441	5,264	2,234	2,081	720	2,170	1,037,117	83,757
Total	21,269	113,207	196,045	24,685	9,982	116,585	4,716,668	2,709,274

Total crop area (ha) 1995
Source: Derived from MAFF (1997) Irrigation Survey

Agency Region	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
North East	416	7,092	1815	0	28	754	917	609
North West	304	1,351	152	0	4	934	356	58
Midlands	1,674	12,107	7,181	70	432	3,685	2,801	2,997
Anglian	4,216	26,854	16,481	1,293	1,067	15,109	2,500	8,751
Thames	210	1,127	280	127	328	1,655	478	114
Southern	739	2,350	0	920	966	3,653	953	0
South West	576	1,086	0	0	166	649	1,177	0
Welsh	1,021	1,030	270	57	157	868	440	10
Total	9,156	52,989	26,179	2,467	3,148	27,302	9,602	12,539

Total irrigated crop area (ha) 1995
Source: Derived from MAFF (1997) Irrigation survey

Agency Region	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
North East	33	38	9	0	7	6	0.2	0.1
North West	19	17	9	0	2	13	0.1	0.1
Midlands	42	53	27	2	27	38	0.4	0.7
Anglian	59	59	12	29	41	21	0.8	0.9
Thames	53	48	23	18	39	50	0.2	0.0
Southern	39	61	0	7	35	47	0.4	0.0
South West	23	17	0	0	22	17	0.1	0.0
Welsh	42	20	12	3	22	40	0.0	0.0

Proportion of total crop area irrigated in 1995
Source: Derived from MAFF (1997) Irrigation Survey

Agency Region	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
North East	161,059	4,726,539	620,527	0	17,284	635,152	188,117	81,243
North West	177,055	1,402,777	75,849	0	3,054	588,622	434,863	15,528
Midlands	1,488,884	18,183,373	6,566,918	49,365	384,735	4,027,344	2,944,828	1,295,924
Anglian	5,351,137	42,770,842	12,908,257	1,363,032	1,024,715	13,815,005	2,369,729	3,868,845
Thames	188,637	1,944,689	271,167	110,252	555,340	1,846,644	545,818	55,397
Southern	573,091	2,436,412	0	580,693	1,823,503	3,407,094	864,910	0
South West	664,444	1,260,889	0	0	243,161	445,581	1,221,530	0
Welsh	691,896	1,152,717	254,992	40,389	151,332	717,438	295,638	4,462
Total	9,296,204	73,877,712	20,697,709	2,143,731	4,203,124	25,480,567	8,857,805	5,321,396

Total volume of water applied (m) 1995
Source: Derived from MAFF (1997) Irrigation Survey

Agency Region	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
North East	39	67	34	0	61	84	21	13
North West	58	104	50	0	81	63	122	27
Midlands	89	150	91	71	89	109	105	43
Anglian	127	159	78	105	96	91	95	44
Thames	90	173	97	87	169	112	114	49
Southern	78	104	0	63	189	93	91	0
South West	115	116	0	0	146	69	104	0
Welsh	68	112	95	71	96	83	67	44

Average depth of irrigation water applied (mm), 1995
Source: Derived from MAFF (1997) Irrigation Survey

Appendix 16

Scenario assumptions and associated growth factors – spray irrigation

Scenario	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
Scenario Alpha	-0.2	-0.2	-0.2	-0.4	0	0	-0.4	0.8
Scenario Beta	-0.32	-0.8	-0.8	-1.24	0	-0.28	-0.4	-0.8
Scenario Gamma	-0.32	-0.8	-0.8	-1.24	0	-0.28	-0.4	-0.8
Scenario Delta	0	0.4	0	0.2	0.4	0.48	-0.4	1

Change in crop area

Scenario	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
Scenario Alpha	2	4	2	3	3	3	-4	-5
Scenario Beta	1	3	0	3	3	2	-5	-8
Scenario Gamma	0	1	-1	1	0	1	-8	-7
Scenario Delta	0	0	0	1	1	1	-8	-7

Change in crop area irrigated

Scenario	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
Scenario Alpha	1	1	0	2	2	2	0	0
Scenario Beta	1	1	0	2	2	2	0	0
Scenario Gamma	0	0	-1	1	1	0	-2	-2
Scenario Delta	0	-1	-1	0	0	0	-3	-4

Change in the depth of water applied, per crop

Scenario	Early potato	Main crop potato	Sugar beet	Orchard fruit	Soft fruit	Vegetable	Grass	Cereal
Scenario Alpha	75	85	85	85	90	90	85	85
Scenario Beta	75	85	85	85	90	90	85	85
Scenario Gamma	85	90	85	95	95	95	90	90
Scenario Delta	80	90	85	90	90	95	85	85

Target level of application efficiency

Appendix 17

Regional and water company total demand by scenario in 2010 and 2025

Anglian Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	172.61	167.17	191.85
	Direct abstraction spray irrigation	252.91	303.79	359.48
	Public water supply household demand	949.26	1,101.82	1,302.66
	Public water supply non-household demand	490.91	551.01	564.69
	Public water supply leakage	336.52	275.85	1,468.07
	Public water supply DSOU and water taken unbilled	30.34	24.95	24.95
	Total demand	2,232.55	2,424.60	3,911.70
Anglian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	611.20	717.51	850.58
	Non-household demand	325.00	358.24	368.42
	Leakage	231.00	183.00	956.00
	DSOU and water taken unbilled	25.00	21.00	21.00
	Total demand	1,192.20	1,279.75	2,196.00
Cambridge Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	39.70	52.06	61.75
	Non-household demand	20.59	23.19	21.26
	Leakage	14.82	15.13	58.30
	DSOU and water taken unbilled	0.40	0.40	0.40
	Total demand	75.51	90.78	141.71
Essex and Suffolk Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	276.69	307.52	362.78
	Non-household demand	138.36	161.39	166.50
	Leakage	84.94	72.70	424.90
	DSOU and water taken unbilled	4.84	3.45	3.45
	Total demand	504.83	545.06	957.62
Tendring Hundred Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	21.67	24.73	27.56
	Non-household demand	6.96	8.19	8.51
	Leakage	5.76	5.02	28.87
	DSOU and water taken unbilled	0.10	0.10	0.10
	Total demand	34.49	38.04	65.04

Midlands Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	505.28	547.84	584.53
	Direct abstraction spray irrigation	105.31	122.98	141.94
	Public water supply household demand	1,204.00	1,373.19	1,657.21
	Public water supply non-household demand	590.50	671.01	738.78
	Public water supply leakage	479.84	400.80	1,838.95
	Public water supply DSOU and water taken unbilled	22.00	29.00	29.00
	Total demand	2,906.93	3,144.83	4,990.41
Severn Trent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,021.78	1,170.17	1,419.03
	Non-household demand	510.15	582.06	650.87
	Leakage	398.00	328.00	1,570.60
	DSOU and water taken unbilled	16.30	23.40	23.40
	Total demand	1,946.23	2,103.63	3,663.90
South Staffordshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	182.22	203.03	238.18
	Non-household demand	80.36	88.95	87.91
	Leakage	81.84	72.80	268.35
	DSOU and water taken unbilled	5.70	5.60	5.60
	Total demand	350.12	370.37	600.04

North East Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	537.88	601.77	652.01
	Direct abstraction spray irrigation	19.86	24.75	31.42
	Public water supply household demand	974.43	1,098.31	1,310.21
	Public water supply non-household demand	586.74	655.84	692.21
	Public water supply leakage	531.92	462.07	1,624.49
	Public water supply DSOU and water taken unbilled	44.51	50.75	50.74
	Total demand	2,695.33	2,893.49	4,361.08
Hartlepool Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	15.14	15.94	17.87
	Non-household demand	16.28	18.18	18.74
	Leakage	4.79	4.72	31.07
	DSOU and water taken unbilled	0.24	0.24	0.24
	Total demand	36.45	39.09	67.92
Northumbrian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	350.84	388.92	453.14
	Non-household demand	238.77	270.31	301.81
	Leakage	183.36	161.98	648.70
	DSOU and water taken unbilled	9.40	14.50	14.50
	Total demand	782.37	835.71	1,418.15
York Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	24.82	29.25	35.61
	Non-household demand	12.07	12.83	11.57
	Leakage	9.08	7.05	36.98
	DSOU and water taken unbilled	0.16	0.19	0.19
	Total demand	46.13	49.32	84.35
Yorkshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	583.62	664.20	803.58
	Non-household demand	319.62	354.51	360.09
	Leakage	334.69	288.32	907.73
	DSOU and water taken unbilled	34.71	35.82	35.81
	Total demand	1,272.64	1,342.85	2,107.22

North West Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	622.35	602.09	610.60
	Direct abstraction spray irrigation	8.36	10.23	13.19
	Public water supply household demand	988.03	1,107.26	1,316.24
	Public water supply non-household demand	535.56	571.43	591.47
	Public water supply leakage	578.88	461.42	1,566.71
	Public water supply DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,760.35	2,777.09	4,123.91
North West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	988.03	1,107.26	1,316.24
	Non-household demand	535.56	571.43	591.47
	Leakage	578.88	461.42	1,566.71
	DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,129.65	2,164.78	3,500.13

South West Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	59.58	62.39	66.83
	Direct abstraction spray irrigation	11.50	12.62	14.88
	Public water supply household demand	628.34	717.24	878.05
	Public water supply non-household demand	383.07	417.48	408.26
	Public water supply leakage	297.23	223.02	1,044.10
	Public water supply DSOU and water taken unbilled	24.30	21.84	22.04
	Total demand	1,404.01	1,454.60	2,434.16
Bournemouth and West Hampshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	64.54	73.71	88.47
	Non-household demand	60.42	65.79	59.38
	Leakage	26.04	23.00	134.53
	DSOU and water taken unbilled	1.80	1.80	1.80
	Total demand	152.79	164.29	284.18
Bristol Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	162.73	183.88	217.99
	Non-household demand	73.07	75.12	67.76
	Leakage	59.34	49.21	258.61
	DSOU and water taken unbilled	5.10	2.94	2.94
	Total demand	300.24	311.15	547.30
South West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	227.73	257.43	321.62
	Non-household demand	119.20	131.75	131.53
	Leakage	101.30	83.90	343.20
	DSOU and water taken unbilled	5.30	5.00	5.20
	Total demand	453.53	478.08	801.56
Wessex Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	173.34	202.22	249.97
	Non-household demand	130.38	144.82	149.58
	Leakage	110.55	66.91	307.76
	DSOU and water taken unbilled	12.10	12.10	12.10
	Total demand	426.37	426.06	719.42

Southern Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	177.89	153.96	136.24
	Direct abstraction spray irrigation	30.23	39.26	46.86
	Public water supply household demand	663.78	747.30	856.45
	Public water supply non-household demand	241.68	259.82	255.43
	Public water supply leakage	214.20	181.93	974.26
	Public water supply DSOU and water taken unbilled	12.68	13.20	13.25
	Total demand	1,340.46	1,395.48	2,282.49
Folkestone and Dover Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	25.43	29.03	33.74
	Non-household demand	12.96	13.81	12.65
	Leakage	8.75	7.93	42.25
	DSOU and water taken unbilled	0.35	0.40	0.40
	Total demand	47.49	51.17	89.04
Mid Kent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.89	96.68	109.65
	Non-household demand	32.50	35.04	35.06
	Leakage	35.68	26.31	128.27
	DSOU and water taken unbilled	1.04	1.51	1.56
	Total demand	155.11	159.54	274.55
Portsmouth Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	101.21	116.73	135.02
	Non-household demand	36.61	41.17	42.50
	Leakage	31.89	31.23	150.46
	DSOU and water taken unbilled	0.57	0.57	0.57
	Total demand	170.28	189.70	328.55
South East Water Kent and Sussex	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	106.54	119.56	136.17
	Non-household demand	39.92	45.26	48.52
	Leakage	38.51	30.27	143.22
	DSOU and water taken unbilled	0.67	0.67	0.67
	Total demand	185.64	195.77	328.58
Southern Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	344.72	385.29	441.88
	Non-household demand	119.68	124.55	116.69
	Leakage	99.37	86.19	510.06
	DSOU and water taken unbilled	10.05	10.05	10.05
	Total demand	573.82	606.08	1,078.68

Thames Region	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	133.51	123.03	118.81
	Direct abstraction spray irrigation	17.14	21.49	25.12
	Public water supply household demand	1,925.56	2,199.05	2,421.26
	Public water supply non-household demand	856.06	945.16	899.82
	Public water supply leakage	1,147.55	783.91	2,783.42
	Public water supply DSOU and water taken unbilled	35.70	31.59	31.32
	Total demand	4,115.52	4,104.22	6,279.76
North Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.75	97.90	104.72
	Non-household demand	34.10	40.84	46.20
	Leakage	24.17	20.95	119.99
	DSOU and water taken unbilled	0.13	0.14	0.14
	Total demand	144.15	159.83	271.05
South East Water Hampshire and Surrey	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	130.85	148.54	177.07
	Non-household demand	64.79	70.13	65.68
	Leakage	54.82	42.07	187.25
	DSOU and water taken unbilled	1.05	1.06	1.06
	Total demand	251.51	261.80	431.06
Sutton and East Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	100.96	111.31	120.25
	Non-household demand	28.59	31.37	29.08
	Leakage	25.85	24.46	131.09
	DSOU and water taken unbilled	0.65	0.75	0.75
	Total demand	156.06	167.89	281.16
Thames Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,188.22	1,361.18	1,498.84
	Non-household demand	592.22	653.15	617.48
	Leakage	894.44	581.72	1,776.24
	DSOU and water taken unbilled	27.16	21.76	21.49
	Total demand	2,702.04	2,617.80	3,914.05
Three Valleys Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	419.78	480.13	520.38
	Non-household demand	136.36	149.67	141.38
	Leakage	148.27	114.71	568.85
	DSOU and water taken unbilled	6.71	7.88	7.88
	Total demand	711.12	752.38	1,238.50

Environment Agency Wales	Scenario Alpha	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	456.25	514.49	622.23
	Direct abstraction spray irrigation	10.26	12.71	15.57
	Public water supply household demand	442.40	487.18	572.01
	Public water supply non-household demand	262.08	299.73	318.20
	Public water supply leakage	342.41	261.03	755.14
	Public water supply DSOU and water taken unbilled	11.90	11.16	12.10
	Total demand	1,525.31	1,586.31	2,295.25

Dee Valley Water	Parameter	1997/98	2009/10	2024/25
	Household demand	34.38	38.46	45.80
	Non-household demand	21.98	25.05	27.84
	Leakage	12.01	10.08	58.78
	DSOU and water taken unbilled	0.20	0.28	0.28
	Total demand	68.57	73.88	132.7

Dŵr Cymru – Welsh Water	Parameter	1997/98	2009/10	2024/25
	Household demand	408.02	448.72	526.21
	Non-household demand	240.10	274.68	290.35
	Leakage	330.40	250.95	696.36
	DSOU and water taken unbilled	11.70	10.88	11.82
	Total demand	990.22	985.22	1,524.75

Anglian Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	172.61	173.07	196.12
	Direct abstraction spray irrigation	252.91	296.81	309.34
	Public water supply household demand	949.26	1,098.78	1,235.64
	Public water supply non-household demand	490.91	579.56	675.87
	Public water supply leakage	336.52	275.85	272.45
	Public water supply DSOU and water taken unbilled	30.34	24.95	24.95
	Total demand	2,232.55	2,449.01	2,714.38

Anglian Water	Parameter	1997/98	2009/10	2024/25
	Household demand	611.20	713.00	808.00
	Non-household demand	325.00	373.99	427.35
	Leakage	231.00	183.00	177.00
	DSOU and water taken unbilled	25.00	21.00	21.00
	Total demand	1,192.20	1,290.99	1,433.35

Cambridge Water	Parameter	1997/98	2009/10	2024/25
	Household demand	39.70	52.08	56.92
	Non-household demand	20.59	24.76	30.32
	Leakage	14.82	15.13	17.67
	DSOU and water taken unbilled	0.40	0.40	0.40
	Total demand	75.51	92.37	105.31

Essex and Suffolk Water	Parameter	1997/98	2009/10	2024/25
	Household demand	276.69	309.08	344.76
	Non-household demand	138.36	172.09	207.66
	Leakage	84.94	72.70	72.70
	DSOU and water taken unbilled	4.84	3.45	3.45
	Total demand	504.83	557.32	628.57

Tendring Hundred Water	Parameter	1997/98	2009/10	2024/25
	Household demand	21.67	24.62	25.96
	Non-household demand	6.96	8.72	10.54
	Leakage	5.76	5.02	5.08
	DSOU and water taken unbilled	0.10	0.10	0.10
	Total demand	34.49	38.46	41.68

Midlands Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	505.28	583.37	656.64
	Direct abstraction spray irrigation	105.31	119.85	121.01
	Public water supply household demand	1,204.00	1,361.92	1,454.73
	Public water supply non-household demand	590.50	711.20	802.95
	Public water supply leakage	479.84	400.80	400.80
	Public water supply DSOU and water taken unbilled	22.00	29.00	29.00
	Total demand	2,906.93	3,206.14	3,465.13
Severn Trent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,021.78	1,161.89	1,246.85
	Non-household demand	510.15	616.69	694.32
	Leakage	398.00	328.00	328.00
	DSOU and water taken unbilled	16.30	23.40	23.40
	Total demand	1,946.23	2,129.98	2,292.57
South Staffordshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	182.22	200.03	207.88
	Non-household demand	80.36	94.51	108.63
	Leakage	81.84	72.80	72.80
	DSOU and water taken unbilled	5.70	5.60	5.60
	Total demand	350.12	372.94	394.91

North East Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	537.88	645.10	747.77
	Direct abstraction spray irrigation	19.86	24.47	27.37
	Public water supply household demand	974.43	1,089.36	1,154.30
	Public water supply non-household demand	586.74	695.66	795.44
	Public water supply leakage	531.92	456.94	443.74
	Public water supply DSOU and water taken unbilled	44.51	50.75	50.74
	Total demand	2,695.33	2,962.28	3,219.36

Hartlepool Water	Parameter	1997/98	2009/10	2024/25
	Household demand	15.14	15.61	15.55
	Non-household demand	16.28	19.28	22.08
	Leakage	4.79	4.72	4.71
	DSOU and water taken unbilled	0.24	0.24	0.24
	Total demand	36.45	39.85	42.59

Northumbrian Water	Parameter	1997/98	2009/10	2024/25
	Household demand	350.84	386.85	393.79
	Non-household demand	238.77	287.24	329.90
	Leakage	183.36	156.85	150.40
	DSOU and water taken unbilled	9.40	14.50	14.50
	Total demand	782.37	845.44	888.59

York Water	Parameter	1997/98	2009/10	2024/25
	Household demand	24.82	29.17	31.51
	Non-household demand	12.07	13.47	15.47
	Leakage	9.08	7.05	6.82
	DSOU and water taken unbilled	0.16	0.19	0.19
	Total demand	46.13	49.87	53.99

Yorkshire Water	Parameter	1997/98	2009/10	2024/25
	Household demand	583.62	657.72	713.45
	Non-household demand	319.62	375.68	427.98
	Leakage	334.69	288.32	281.81
	DSOU and water taken unbilled	34.71	35.82	35.81
	Total demand	1,272.64	1,357.54	1,459.04

North West Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	622.35	639.49	624.54
	Direct abstraction spray irrigation	8.36	10.06	11.46
	Public water supply household demand	988.03	1,097.82	1,149.75
	Public water supply non household demand	535.56	604.54	666.74
	Public water supply leakage	578.88	461.42	460.90
	Public water supply DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,760.35	2,837.99	2,939.11

North West Water	Parameter	1997/98	2009/10	2024/25
	Household demand	988.03	1,097.82	1,149.75
	Non-household demand	535.56	604.54	666.74
	Leakage	578.88	461.42	460.90
	DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,129.65	2,188.45	2,303.10

South West Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	59.58	64.53	62.38
	Direct abstraction spray irrigation	11.50	12.35	13.08
	Public water supply household demand	628.34	708.17	792.56
	Public water supply non-household demand	383.07	439.79	502.87
	Public water supply leakage	297.23	223.02	219.38
	Public water supply DSOU and water taken unbilled	24.30	21.84	22.04
	Total demand	1,404.01	1,469.70	1,612.30
Bournemouth and West Hampshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	64.54	73.35	80.77
	Non-household demand	60.42	69.68	84.35
	Leakage	26.04	23.00	23.00
	DSOU and water taken unbilled	1.80	1.80	1.80
	Total demand	152.79	167.84	189.92
Bristol Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	162.73	181.54	192.30
	Non-household demand	73.07	80.26	87.50
	Leakage	59.34	49.21	46.00
	DSOU and water taken unbilled	5.10	2.94	2.94
	Total demand	300.24	313.95	328.75
South West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	227.73	253.46	290.34
	Non-household demand	119.20	138.16	160.15
	Leakage	101.30	83.90	83.90
	DSOU and water taken unbilled	5.30	5.00	5.20
	Total demand	453.53	480.53	539.58
Wessex Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	173.34	199.81	229.16
	Non-household demand	130.38	151.69	170.87
	Leakage	110.55	66.91	66.48
	DSOU and water taken unbilled	12.10	12.10	12.10
	Total demand	426.37	430.51	478.60

Southern Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	177.89	161.56	116.25
	Direct abstraction spray irrigation	30.23	38.55	42.82
	Public water supply household demand	663.78	745.70	789.77
	Public water supply non-household demand	241.68	273.76	304.70
	Public water supply leakage	214.20	181.93	182.66
	Public water supply DSOU and water taken unbilled	12.68	13.20	13.25
	Total demand	1,340.46	1,414.70	1,449.46
Folkestone and Dover Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	25.43	28.84	31.42
	Non-household demand	12.96	14.57	16.46
	Leakage	8.75	7.93	7.93
	DSOU and water taken unbilled	0.35	0.40	0.40
	Total demand	47.49	51.74	56.21
Mid Kent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.89	96.59	102.25
	Non-household demand	32.50	36.49	40.61
	Leakage	35.68	26.31	26.27
	DSOU and water taken unbilled	1.04	1.51	1.56
	Total demand	155.11	160.91	170.69
Portsmouth Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	101.21	116.60	123.76
	Non-household demand	36.61	43.56	49.92
	Leakage	31.89	31.23	32.20
	DSOU and water taken unbilled	0.57	0.57	0.57
	Total demand	170.28	191.95	206.45
South East Water Kent and Sussex	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	106.54	119.21	122.65
	Non-household demand	39.92	47.56	53.03
	Leakage	38.51	30.27	30.87
	DSOU and water taken unbilled	0.67	0.67	0.67
	Total demand	185.64	197.72	207.22
Southern Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	344.72	384.46	409.70
	Non-household demand	119.68	131.57	144.69
	Leakage	99.37	86.19	85.39
	DSOU and water taken unbilled	10.05	10.05	10.05
	Total demand	573.82	612.27	649.83

Thames Region	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	133.51	126.57	112.97
	Direct abstraction spray irrigation	17.14	21.07	22.62
	Public water supply household demand	1,925.56	2,184.81	2,192.12
	Public water supply non-household demand	856.06	1,011.78	1,184.06
	Public water supply leakage	1,147.55	783.91	784.34
	Public water supply DSOU and water taken unbilled	35.70	31.59	31.32
	Total demand	4,115.52	4,159.72	4,327.42
North Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.75	97.76	96.26
	Non-household demand	34.10	43.07	48.89
	Leakage	24.17	20.95	20.90
	DSOU and water taken unbilled	0.13	0.14	0.14
	Total demand	144.15	161.92	166.19
South East Water Hampshire and Surrey	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	130.85	149.13	159.73
	Non-household demand	64.79	74.77	84.69
	Leakage	54.82	42.07	42.29
	DSOU and water taken unbilled	1.05	1.06	1.06
	Total demand	251.51	267.03	287.77
Sutton and East Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	100.96	111.54	115.34
	Non-household demand	28.59	33.70	39.17
	Leakage	25.85	24.46	24.46
	DSOU and water taken unbilled	0.65	0.75	0.75
	Total demand	156.06	170.44	179.71
Thames Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,188.22	1,346.16	1,333.82
	Non-household demand	592.22	699.88	825.29
	Leakage	894.44	581.72	581.98
	DSOU and water taken unbilled	27.16	21.76	21.49
	Total demand	2,702.04	2,649.52	2,762.58
Three Valleys Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	419.78	480.22	486.97
	Non-household demand	136.36	160.37	186.03
	Leakage	148.27	114.71	114.71
	DSOU and water taken unbilled	6.71	7.88	7.88
	Total demand	711.12	763.18	795.58

Environment Agency Wales	Scenario Beta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	456.25	516.35	573.83
	Direct abstraction spray irrigation	10.26	12.44	13.63
	Public water supply household demand	442.40	481.47	504.72
	Public water supply non-household demand	262.08	316.22	376.75
	Public water supply leakage	342.41	262.60	287.87
	Public water supply DSOU and water taken unbilled	11.90	11.16	12.10
	Total demand	1,525.31	1,600.25	1,768.90
Dee Valley Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	34.38	38.14	40.60
	Non-household demand	21.98	26.57	30.34
	Leakage	12.01	10.08	9.91
	DSOU and water taken unbilled	0.20	0.28	0.28
	Total demand	68.57	75.08	81.13
Dŵr Cymru – Welsh Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	408.02	443.33	464.12
	Non-household demand	240.10	289.65	346.41
	Leakage	330.40	252.52	277.96
	DSOU and water taken unbilled	11.70	10.88	11.82
	Total demand	990.22	996.38	1,100.32

Anglian Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	172.61	138.38	83.90
	Direct abstraction spray irrigation	252.91	272.98	220.66
	Public water supply household demand	949.26	1,000.72	738.39
	Public water supply non-household demand	490.91	503.96	391.53
	Public water supply leakage	336.52	277.72	188.09
	Public water supply DSOU and water taken unbilled	30.34	24.95	24.95
	Total demand	2,232.55	2,218.72	1,647.52
Anglian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	611.20	649.29	488.31
	Non-household demand	325.00	330.78	262.06
	Leakage	231.00	195.58	130.27
	DSOU and water taken unbilled	25.00	21.00	21.00
	Total demand	1,192.20	1,196.65	901.64
Cambridge Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	39.70	44.85	33.93
	Non-household demand	20.59	21.97	18.44
	Leakage	14.82	14.27	10.21
	DSOU and water taken unbilled	0.40	0.40	0.40
	Total demand	75.51	81.49	62.98
Essex and Suffolk Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	276.69	284.57	199.94
	Non-household demand	138.36	143.80	105.43
	Leakage	84.94	61.05	41.69
	DSOU and water taken unbilled	4.84	3.45	3.45
	Total demand	504.83	492.87	350.50
Tendring Hundred Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	21.67	22.01	16.21
	Non-household demand	6.96	7.41	5.60
	Leakage	5.76	6.82	5.92
	DSOU and water taken unbilled	0.10	0.10	0.10
	Total demand	34.49	36.35	27.83

Midlands Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	505.28	441.23	226.85
	Direct abstraction spray irrigation	105.31	109.93	86.19
	Public water supply household demand	1,204.00	1,236.71	864.36
	Public water supply non-household demand	590.50	602.72	427.82
	Public water supply leakage	479.84	300.83	222.68
	Public water supply DSOU and water taken unbilled	22.00	29.00	29.00
	Total demand	2,906.93	2,720.42	1,856.90
Severn Trent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,021.78	1,054.20	739.43
	Non-household demand	510.15	522.00	367.62
	Leakage	398.00	249.83	187.21
	DSOU and water taken unbilled	16.30	23.40	23.40
	Total demand	1,946.23	1,849.43	1,317.66
South Staffordshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	182.22	182.51	124.92
	Non-household demand	80.36	80.73	60.21
	Leakage	81.84	51.00	35.47
	DSOU and water taken unbilled	5.70	5.60	5.60
	Total demand	350.12	319.84	226.20

North East Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	537.88	474.75	232.82
	Direct abstraction spray irrigation	19.86	22.25	18.63
	Public water supply household demand	974.43	982.65	670.23
	Public water supply non-household demand	586.74	568.62	369.71
	Public water supply leakage	531.92	407.23	302.85
	Public water supply DSOU and water taken unbilled	44.51	50.75	50.74
	Total demand	2,695.33	2,506.26	1,644.99
Hartlepool Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	15.14	14.33	9.46
	Non-household demand	16.28	16.07	11.03
	Leakage	4.79	4.14	3.26
	DSOU and water taken unbilled	0.24	0.24	0.24
	Total demand	36.45	34.78	23.99
Northumbrian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	350.84	350.35	230.78
	Non-household demand	238.77	223.19	131.97
	Leakage	183.36	146.43	122.01
	DSOU and water taken unbilled	9.40	14.50	14.50
	Total demand	782.37	734.47	499.25
York Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	24.82	26.11	17.50
	Non-household demand	12.07	12.29	10.16
	Leakage	9.08	6.91	5.91
	DSOU and water taken unbilled	0.16	0.19	0.19
	Total demand	46.13	45.50	33.75
Yorkshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	583.62	591.86	412.51
	Non-household demand	319.62	317.06	216.55
	Leakage	334.69	249.75	171.67
	DSOU and water taken unbilled	34.71	35.82	35.81
	Total demand	1,272.64	1,194.50	836.54

North West Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	622.35	504.89	236.70
	Direct abstraction spray irrigation	8.36	9.09	7.68
	Public water supply household demand	988.03	999.82	688.00
	Public water supply non-household demand	535.56	499.03	313.54
	Public water supply leakage	578.88	372.35	270.56
	Public water supply DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,760.35	2,409.84	1,542.19
North West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	988.03	999.82	688.00
	Non-household demand	535.56	499.03	313.54
	Leakage	578.88	372.35	270.56
	DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,129.65	1,895.86	1,297.81

South West Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	59.58	53.68	32.05
	Direct abstraction spray irrigation	11.50	11.15	8.82
	Public water supply household demand	628.34	646.16	488.65
	Public water supply non-household demand	383.07	395.30	331.21
	Public water supply leakage	297.23	189.77	145.77
	Public water supply DSOU and water taken unbilled	24.30	21.84	22.04
	Total demand	1,404.01	1,317.90	1,028.54
Bournemouth and West Hampshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	64.54	66.82	50.71
	Non-household demand	60.42	62.85	54.99
	Leakage	26.04	15.74	12.18
	DSOU and water taken unbilled	1.80	1.80	1.80
	Total demand	152.79	147.21	119.68
Bristol Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	162.73	165.32	118.52
	Non-household demand	73.07	68.10	49.51
	Leakage	59.34	39.79	30.95
	DSOU and water taken unbilled	5.10	2.94	2.94
	Total demand	300.24	276.16	201.92
South West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	227.73	231.72	179.73
	Non-household demand	119.20	125.51	107.93
	Leakage	101.30	82.42	61.50
	DSOU and water taken unbilled	5.30	5.00	5.20
	Total demand	453.53	444.65	354.36
Wessex Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	173.34	182.29	139.68
	Non-household demand	130.38	138.84	118.79
	Leakage	110.55	51.82	41.14
	DSOU and water taken unbilled	12.10	12.10	12.10
	Total demand	426.37	385.05	311.71

Southern Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	177.890	134.074	61.309
	Direct abstraction spray irrigation	30.232	35.285	30.646
	Public water supply household demand	663.779	678.180	478.414
	Public water supply non-household demand	241.681	242.298	183.732
	Public water supply leakage	214.200	187.654	133.403
	Public water supply DSOU and water taken unbilled	12.680	13.200	13.250
	Total demand	1,340.462	1,290.691	900.754
Folkestone and Dover Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	25.43	26.51	19.30
	Non-household demand	12.96	13.32	10.91
	Leakage	8.75	5.91	4.76
	DSOU and water taken unbilled	0.35	0.40	0.40
	Total demand	47.49	46.13	35.37
Mid Kent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.89	87.82	61.26
	Non-household demand	32.50	33.38	28.27
	Leakage	35.68	23.05	16.62
	DSOU and water taken unbilled	1.04	1.51	1.56
	Total demand	155.11	145.75	107.71
Portsmouth Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	101.21	105.55	73.76
	Non-household demand	36.61	38.35	27.93
	Leakage	31.89	37.79	24.47
	DSOU and water taken unbilled	0.57	0.57	0.57
	Total demand	170.28	182.26	126.73
South East Water Kent and Sussex	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	106.54	108.72	77.46
	Non-household demand	39.92	41.68	31.17
	Leakage	38.51	22.50	16.83
	DSOU and water taken unbilled	0.67	0.67	0.67
	Total demand	185.64	173.57	126.13
Southern Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	344.72	349.59	246.63
	Non-household demand	119.68	115.57	85.45
	Leakage	99.37	98.40	70.72
	DSOU and water taken unbilled	10.05	10.05	10.05
	Total demand	573.82	573.61	412.86

Thames Region	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	133.51	105.25	55.94
	Direct abstraction spray irrigation	17.14	19.33	16.41
	Public water supply household demand	1,925.56	2,004.73	1,372.03
	Public water supply non-household demand	856.06	841.86	578.19
	Public water supply leakage	1,147.55	438.65	318.24
	Public water supply DSOU and water taken unbilled	35.70	31.59	31.32
	Total demand	4,115.52	3,441.40	2,372.14
North Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	85.75	88.94	61.43
	Non-household demand	34.10	37.87	29.73
	Leakage	24.17	19.39	12.60
	DSOU and water taken unbilled	0.13	0.14	0.14
	Total demand	144.15	146.34	103.90
South East Water Hampshire and Surrey	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	130.85	138.35	95.86
	Non-household demand	64.79	63.63	45.16
	Leakage	54.82	30.87	23.09
	DSOU and water taken unbilled	1.05	1.06	1.06
	Total demand	251.51	233.90	165.18
Sutton and East Surrey Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	100.96	99.95	69.14
	Non-household demand	28.59	28.14	19.03
	Leakage	25.85	23.37	19.70
	DSOU and water taken unbilled	0.65	0.75	0.75
	Total demand	156.06	152.21	108.62
Thames Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,188.22	1,245.32	847.44
	Non-household demand	592.22	579.16	394.18
	Leakage	894.44	277.11	206.76
	DSOU and water taken unbilled	27.16	21.76	21.49
	Total demand	2,702.04	2,123.35	1,469.87
Three Valleys Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	419.78	432.17	298.17
	Non-household demand	136.36	133.07	90.08
	Leakage	148.27	87.91	56.09
	DSOU and water taken unbilled	6.71	7.88	7.88
	Total demand	711.12	661.03	452.23

Environment Agency Wales	Scenario Gamma	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	456.25	466.53	298.06
	Direct abstraction spray irrigation	10.26	11.37	9.54
	Public water supply household demand	442.40	435.35	301.73
	Public water supply non-household demand	262.10	273.76	210.45
	Public water supply leakage	342.41	200.08	128.09
	Public water supply DSOU and water taken unbilled	11.90	11.16	12.10
	Total demand	1,525.32	1,398.24	959.96
Dee Valley Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	34.38	34.56	23.67
	Non-household demand	22.00	23.51	18.82
	Leakage	12.01	8.08	6.00
	DSOU and water taken unbilled	0.20	0.28	0.28
	Total demand	68.59	66.43	48.77
Dŵr Cymru – Welsh Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	408.02	400.79	278.06
	Non-household demand	240.10	250.25	191.63
	Leakage	330.40	192.00	122.09
	DSOU and water taken unbilled	11.70	10.88	11.82
	Total demand	990.22	853.92	603.60

Anglian Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	172.61	133.33	92.87
	Direct abstraction spray irrigation	252.91	303.79	269.01
	Public water supply household demand	949.26	1,037.02	771.64
	Public water supply non-household demand	490.91	459.79	349.85
	Public water supply leakage	336.52	275.85	210.04
	Public water supply DSOU and water taken unbilled	30.34	24.95	24.95
	Total demand	2,232.55	2,234.74	1,718.36
Anglian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	611.20	673.81	512.08
	Non-household demand	325.00	303.83	237.71
	Leakage	231.00	183.00	137.49
	DSOU and water taken unbilled	25.00	21.00	21.00
	Total demand	1,192.20	1,181.63	908.28
Cambridge Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	39.70	46.30	36.26
	Non-household demand	20.59	19.17	13.43
	Leakage	14.82	15.13	11.37
	DSOU and water taken unbilled	0.40	0.40	0.40
	Total demand	75.51	81.00	61.45
Essex and Suffolk Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	276.69	294.21	207.48
	Non-household demand	138.36	130.08	93.68
	Leakage	84.94	72.70	57.42
	DSOU and water taken unbilled	4.84	3.45	3.45
	Total demand	504.83	500.44	362.03
Tendring Hundred Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	21.67	22.71	15.81
	Non-household demand	6.96	6.70	5.03
	Leakage	5.76	5.02	3.77
	DSOU and water taken unbilled	0.10	0.10	0.10
	Total demand	34.49	34.53	24.71

Midlands Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	505.28	421.12	260.69
	Direct abstraction spray irrigation	105.31	122.98	105.23
	Public water supply household demand	1,204.00	1,272.57	978.61
	Public water supply non-household demand	590.50	552.01	410.57
	Public water supply leakage	479.84	400.80	301.12
	Public water supply DSOU and water taken unbilled	22.00	29.00	29.00
	Total demand	2,906.93	2,798.49	2,085.22
Severn Trent Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	1,021.78	1,084.65	836.81
	Non-household demand	510.15	478.73	357.25
	Leakage	398.00	328.00	246.43
	DSOU and water taken unbilled	16.30	23.40	23.40
	Total demand	1,946.23	1,914.78	1,463.88
South Staffordshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	182.22	187.93	141.81
	Non-household demand	80.36	73.28	53.32
	Leakage	81.84	72.80	54.69
	DSOU and water taken unbilled	5.70	5.60	5.60
	Total demand	350.12	339.61	255.42

North East Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	537.88	454.69	288.20
	Direct abstraction spray irrigation	19.86	24.75	21.64
	Public water supply household demand	974.43	1,011.32	765.11
	Public water supply non-household demand	586.74	520.69	356.49
	Public water supply leakage	531.92	457.00	344.53
	Public water supply DSOU and water taken unbilled	44.51	50.75	50.74
	Total demand	2,695.33	2,519.21	1,826.71
Hartlepool Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	15.14	14.78	10.80
	Non-household demand	16.28	14.40	8.96
	Leakage	4.79	4.79	4.79
	DSOU and water taken unbilled	0.24	0.24	0.24
	Total demand	36.45	34.20	24.79
Northumbrian Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	350.84	359.57	267.00
	Non-household demand	238.77	210.29	143.31
	Leakage	183.36	156.85	117.84
	DSOU and water taken unbilled	9.40	14.50	14.50
	Total demand	782.37	741.20	542.65
York Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	24.82	26.94	19.30
	Non-household demand	12.07	10.78	7.95
	Leakage	9.08	7.05	5.29
	DSOU and water taken unbilled	0.16	0.19	0.19
	Total demand	46.13	44.96	32.73
Yorkshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	583.62	610.03	468.01
	Non-household demand	319.62	285.23	196.27
	Leakage	334.69	288.32	216.61
	DSOU and water taken unbilled	34.71	35.82	35.81
	Total demand	1,272.64	1,219.40	916.70

North West Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	622.35	488.22	283.21
	Direct abstraction spray irrigation	10.26	12.71	11.56
	Public water supply household demand	988.03	1,028.23	781.98
	Public water supply non-household demand	535.56	455.84	304.65
	Public water supply leakage	578.88	461.42	346.66
	Public water supply DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,762.26	2,471.10	1,753.78
North West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	988.03	1,028.23	781.98
	Non-household demand	535.56	455.84	304.65
	Leakage	578.88	461.42	346.66
	DSOU and water taken unbilled	27.18	24.67	25.72
	Total demand	2,129.65	1,970.17	1,459.00

South West Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	59.58	51.92	35.10
	Direct abstraction spray irrigation	11.50	12.62	10.47
	Public water supply household demand	628.34	668.45	523.78
	Public water supply non-household demand	383.07	354.69	275.99
	Public water supply leakage	297.23	223.02	168.42
	Public water supply DSOU and water taken unbilled	24.30	21.84	22.04
	Total demand	1,404.01	1,332.56	1,035.80
Bournemouth and West Hampshire Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	64.54	68.89	53.62
	Non-household demand	60.42	53.84	38.07
	Leakage	26.04	23.00	18.15
	DSOU and water taken unbilled	1.80	1.80	1.80
	Total demand	152.79	147.53	111.63
Bristol Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	162.73	170.90	126.83
	Non-household demand	73.07	60.90	40.91
	Leakage	59.34	49.21	36.97
	DSOU and water taken unbilled	5.10	2.94	2.94
	Total demand	300.24	283.96	207.65
South West Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	227.73	240.14	200.99
	Non-household demand	119.20	112.62	89.61
	Leakage	101.30	83.90	63.03
	DSOU and water taken unbilled	5.30	5.00	5.20
	Total demand	453.53	441.66	358.83
Wessex Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household demand	173.34	188.52	142.35
	Non-household demand	130.38	127.33	107.40
	Leakage	110.55	66.91	50.27
	DSOU and water taken unbilled	12.10	12.10	12.10
	Total demand	426.37	394.86	312.11

Southern Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	177.89	130.64	74.26
	Direct abstraction spray irrigation	30.23	39.26	37.76
	Public water supply household demand	663.78	700.69	509.73
	Public water supply non-household demand	241.68	217.90	158.98
	Public water supply leakage	214.20	181.93	136.69
	Public water supply DSOU and water taken unbilled	12.68	13.20	13.25
	Total demand	1,340.46	1,283.62	930.66

Folkestone and Dover Water	Parameter	1997/98	2009/10	2024/25
	Household demand	25.43	27.44	20.09
	Non-household demand	12.96	11.95	8.83
	Leakage	8.75	7.93	5.96
	DSOU and water taken unbilled	0.35	0.40	0.40
	Total demand	47.49	47.72	35.28

Mid Kent Water	Parameter	1997/98	2009/10	2024/25
	Household demand	85.89	90.94	66.26
	Non-household demand	32.50	30.53	24.73
	Leakage	35.68	26.31	19.77
	DSOU and water taken unbilled	1.04	1.51	1.56
	Total demand	155.11	149.29	112.32

Portsmouth Water	Parameter	1997/98	2009/10	2024/25
	Household demand	101.21	108.67	77.26
	Non-household demand	36.61	34.20	24.61
	Leakage	31.89	31.23	23.46
	DSOU and water taken unbilled	0.57	0.57	0.57
	Total demand	170.28	174.67	125.91

South East Water Kent and Sussex	Parameter	1997/98	2009/10	2024/25
	Household demand	106.54	111.77	75.79
	Non-household demand	39.92	37.85	28.25
	Leakage	38.51	30.27	22.75
	DSOU and water taken unbilled	0.67	0.67	0.67
	Total demand	185.64	180.57	127.45

Southern Water	Parameter	1997/98	2009/10	2024/25
	Household demand	344.72	361.87	270.32
	Non-household demand	119.68	103.37	72.55
	Leakage	99.37	86.19	64.75
	DSOU and water taken unbilled	10.05	10.05	10.05
	Total demand	573.82	561.48	417.67

Thames Region	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	133.51	101.64	61.02
	Direct abstraction spray irrigation	17.14	21.49	19.82
	Public water supply household demand	1,925.56	2,067.66	1,527.30
	Public water supply non-household demand	856.06	752.30	485.62
	Public water supply leakage	1,147.55	783.91	588.94
	Public water supply DSOU and water taken unbilled	35.70	31.59	31.32
	Total demand	4,115.52	3,758.58	2,714.03

North Surrey Water	Parameter	1997/98	2009/10	2024/25
	Household demand	85.75	91.34	58.13
	Non-household demand	34.10	34.74	27.71
	Leakage	24.17	20.95	15.74
	DSOU and water taken unbilled	0.13	0.14	0.14
	Total demand	144.15	147.17	101.72

South East Water Hampshire and Surrey	Parameter	1997/98	2009/10	2024/25
	Household demand	130.85	142.14	92.96
	Non-household demand	64.79	57.06	38.41
	Leakage	54.82	42.07	31.60
	DSOU and water taken unbilled	1.05	1.06	1.06
	Total demand	251.51	242.33	164.03

Sutton and East Surrey Water	Parameter	1997/98	2009/10	2024/25
	Household demand	100.96	103.41	73.60
	Non-household demand	28.59	24.92	15.78
	Leakage	25.85	24.46	18.38
	DSOU and water taken unbilled	0.65	0.75	0.75
	Total demand	156.06	153.54	108.51

Thames Water	Parameter	1997/98	2009/10	2024/25
	Household demand	1,188.22	1,285.63	994.52
	Non-household demand	592.22	516.70	327.75
	Leakage	894.44	581.72	437.04
	DSOU and water taken unbilled	27.16	21.76	21.49
	Total demand	2,702.04	2,405.81	1,780.81

Three Valleys Water	Parameter	1997/98	2009/10	2024/25
	Household demand	419.78	445.14	308.10
	Non-household demand	136.36	118.88	75.96
	Leakage	148.27	114.71	86.18
	DSOU and water taken unbilled	6.71	7.88	7.88
	Total demand	711.12	686.60	478.12

Environment Agency Wales	Scenario Delta	1997/98	2009/10	2024/25
	Direct abstraction industry and commerce	456.25	443.66	350.78
	Direct abstraction spray irrigation	10.26	12.71	11.56
	Public water supply household demand	442.40	449.45	342.66
	Public water supply non household demand	262.08	246.06	186.07
	Public water supply leakage	342.41	262.60	203.84
	Public water supply DSOU and water taken unbilled	11.90	11.16	12.10
	Total Demand	1,525.31	1,425.64	1,107.01
Dee Valley Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household Demand	34.38	35.67	26.48
	Non Household Demand	21.98	21.49	18.27
	Leakage	12.01	10.08	7.57
	DSOU and water taken unbilled	0.20	0.28	0.28
	Total Demand	68.57	67.52	52.61
Dŵr Cymru – Welsh Water	**Parameter**	**1997/98**	**2009/10**	**2024/25**
	Household Demand	408.02	413.78	316.17
	Non Household Demand	240.10	224.57	167.80
	Leakage	330.40	252.52	196.26
	DSOU and water taken unbilled	11.70	10.88	11.82
	Total Demand	990.22	901.74	692.06

Appendix 18
Consultees

- Allan Lambert
- American Water Works Association
- Building Research Establishment Ltd
- British Bathroom Council (now the British Bathroom Association)
- CACI Ltd
- Confederation of British Industry
- Country Landowners Association
- Department of the Environment, Transport and the Regions (Now the Department for Environment, Food and Rural Affairs)
- ENVIROWISE formerly (ETBPP)
- Horticultural Trade Association
- IMPEL Climate Impact Assessment project
- Ministry of Agriculture, Fisheries and Food
- National Centre for Risk and Options Appraisal, Environment Agency
- National Farmers Union
- National Institute of Agricultural Botany
- Office of National Statistics
- Paul Herrington
- REGIS Climate Impact Assessment project
- Royal Horticultural Society
- Soil Association
- UK Irigation Association

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Glossary of terms

Term	Definition
ACORN	A Classification Of Residential Neighbourhoods, based on socio-economic information primarily collated from household census data and market research
Active leakage control	Responding to leaks and burst reported by water utility monitoring systems
Agro-climatic zones	Areas with common climate conditions that lead to similar crop growth patterns
AOD	Above ordnance datum
AWC	Available water capacity
AZNP	Average zone night pressure
BABE	Bursts and background estimates
Background leakage	Leaks with flowrates < 500 litres/hour
Base year	The year from which forecast assumptions are applied (1997/98)
BAT	Best available technology
BATNEEC	Best available technology not entailing excessive costs
BRE	Building Research Establishment
BSL	Business Services Limited
Bursts	Leaks with flowrates > 500 litres/hour
CACI Ltd	CACI Information Services: direct marketing, market analysis, information systems
CAP	Common Agricultural Policy
CBI	Confederation of British Industry
Communication pipe	That part of the service pipe between the distribution main and the highway boundary
Consumption	Water delivered billed less underground supply pipe losses. Consumption can be split into customer use plus total plumbing losses
Deficit irrigation	Depending on the stage of crop growth, the depth of irrigation water applied whereby the soil is not brought back to field capacity
DETR	Department of the Environment, Transport and the Regions
Distribution input	The amount of water entering the distribution system at the point of production

Distribution system operational use (DSOU)	Water knowingly used by a company to meet its statutory obligations, particularly those relating to water quality. Examples include mains flushing and air scouring
DMA	District meter area: a discrete area of the water distribution network comprising up to 2,000 properties, where flow is recorded for the purposes of leakage monitoring
Dry year (household)	A period of low rainfall and high unconstrained demand. In this report we have assumed 1995 to represent of a dry year
Econometric forecast	Forecast derived on the basis of the past statistical relationship between demand and its determinants
EMAS	Eco-Management and Audit Scheme of the European Union
EMU	European Monetary Union
External metering	Meters located at the property boundary that record underground supply pipe losses as well as consumption
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
Greywater	Water that can be considered for non-potable reuse
IMPEL	Integrated Model to Predict European Land Use
Irrigation schedules	Provide the irrigator with information on crop water needs to ensure that irrigation applications are timely and of sufficient quantity
ISO 14001	International Standards Organisations (ISO) 14001 standards related to Environmental Management Systems (EMSs)
l/h/d	Litres per head per day – unit of per capita consumption, generally applied to household demand
MAFF	Ministry of Agriculture, Fisheries and Food
Measured household	Describes water users who pay for water on the basis of the volume consumed
Micro-component	A sub-component of household demand (for example WC use, shower use, etc.)
Ml/d	Megalitres per day. Megalitre = one million litres (1,000 cubic metres)
NALD	National Abstraction Licensing Database operated by the Agency
NMT	National Metering Trials
NRA	National Rivers Authority
NRR	Natural rate of rise of leakage
OFV	Collectively reference to Ownership, Frequency and Volume of each household micro-component
Ofwat	Office of Water Services. The economic regulator of the water and sewerage industry in England and Wales
ONS	Office of National Statistics
OR	Occupancy rate

Passive leakage control	A policy of responding only to leaks and bursts reported by the public
Pcc	Per capita consumption (consumption per head of population)
Pressure-reducing valve (PRV)	A device in the water distribution system that reduces the mains pressure. Mainly used as a method of leakage control
PSMD	Potential soil moisture deficit
PWS	Public water supply. Used to describe the supply of water provided by a water undertaker
REGIS	Regional Climate Change Impact and Response Studies in East Anglia and North West England
Reported bursts	Bursts reported to the water utility by the public
Resource zone	The largest area in which all resources, including external transfers, can be shared to ensure that all customers experience the same risk of supply failure from a resource shortfall
Service pipe	The sum of the communication pipe and the supply pipe
SIC	Standard Industrial Classification
SMEs	Small and medium-sized enterprises. Describes businesses with less that 250 employees
Supply pipe	That part of the service pipe not within the boundary of the highway (that is, within the property boundary)
UKCIP	United Kingdom Climate Impacts Programme
UKWIR	United Kingdom Water Industry Research
Unmeasured household	Water users who are charged for water by a flat-rate unrelated to the volume consumed
Unreported bursts	Bursts found by active leakage control
Water recycling	Water used again within the same industrial process.
Water reuse	Water used in a different process to the original industrial process
WRP	Water resources plans
WTO	World Trade Organisation