NRA - SOUTHWEST 521

National Rivers Authority
South West Region

WATER RESOURCES DEVELOPMENT STRATEGY

Final Report

April 1992

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For the attention of Mr C V M Davies
Environmental Protection Officer

15 April 1992 Our ref: WE/RDS/7/025 Your ref:

Dear Sirs

WATER RESOURCES DEVELOPMENT STRATEGY

Please find enclosed 15 copies of our Final Report. As requested, one of these copies is unbound.

I trust that you will find this Report in accordance with your requirements.

Yours faithfully

J D Lawson

J D LAWSON

Encs


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Okehampton
Launceston
SOUTH WEST N.R.A. REGION
Tavistock
Newton Abbot
COLLIFORD
Wadebridge
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Fowey
ROADFORD PLYMOUTH
ROADFORD SOUTH WEST DEVON
St.Austell
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Frontispiece

NRA SOUTH WEST REGION

WATER RESOURCES DEVELOPMENT STRATEGY

FINAL REPORT

APRIL 1992

REPORT AUTHORISATION

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NRA SOUTH WEST REGION

WATER RESOURCES DEVELOPMENT STRATEGY

FINAL REPORT

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Water Resources Development Strategy

Draft Final Report

NRA South West Region

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GLOSSARY

Alleviation of low flows: (ALF). Collective measures to ensure that abstraction rates from rivers and aquifers are not detrimental to surface water base flows.

Compensation Water: A prescribed release from a reservoir to maintain a minimum flow in the river downstream.

Conjunctive Use: The joint use of different facets of the water resource in a single operational strategy, for example the joint use of groundwater and reservoirs.

Critical Period: The period during which a reservoir passes from a full condition to empty, without spilling in the intervening period.

Direct Supply Reservoir: Generally an upland storage supported by natural catchment inflow. Raw water is released to a pressure conduit for gravity fed direct supply.

Drought Reliable Yield: Defines the output capacity of a reservoir, reservoir system, conjunctive use scheme etc. It is the amount that can just be sustained in a design drought period by the combination of inflow and usable storage. 1976 is generally regarded as the critical historical sequence, with a risk of occurrence regionally of approximately 1:50 years. A review of its return frequency at various meteorological stations in Somerset gave a range of 1:10 years to 1:95 years (19).

Minimum Acceptable Flow (MAF): A prescribed flow in a river set in order to protect the riverine and fisheries environment and/or to ensure the acceptable dilution of effluent discharges and protection of legitimate riparian interests.

Operational District: a sub-division of the overall SWWSL water supply area, for the purposes of local operations and management eg Fal, Fowey, Tamar etc. Now substantially replaced by "supply zones" for resource planning purposes (see below).

Private Abstraction: Abstractions, subject to licence, that are operated by parties other than the established water companies, to satisfy demands for water not met via the public supply system.

Private demand: demand for water which is satisfied by means of private abstractions.

Public Water Supply: Bulk water supplied to the distribution system.

Pumped Storage: Classically, bunded off-channel reservoirs where there is little or no natural inflow, and where water is pumped from the adjacent river for storage.

Resource Integration: The combination of water supply components, for example, reservoirs and groundwater into an increasingly complex linked system to achieve operational benefits.

River Regulation: Generally refers to reservoir storage that is used wholly or partially for the augmentation of low flows in order to support direct river abstractions further downstream.

Strategic Option: A scheme or combination of schemes which form part of the long term response to regional or inter-regional demand growth, usually with a planning horizon of 25-30 years.

Supply Zone: a sub-division of the overall SWWSL water supply area, usually reflecting the areas which can be fed by the strategic reservoirs, eg Colliford and Wimbleball supply zones.

Unaccounted for Water (UFW): Generally refers to leakage, but cannot be determined directly unless public supply is metered. Definitions vary but is generally the discrepancy between water supplied and that used, or the residual component once metered and un-metered domestic and industrial demands are subtracted from the total volume of water supplied.

1 INTRODUCTION AND SUMMARY

1.1 Introduction

In November 1990, the National Rivers Authority (NRA) South West Region appointed Sir William Halcrow and Partners Ltd to develop a water resources strategy for the Region. The area of study was to include the entire South West Water Services Ltd (SWWSL) supply area, together with that part of the Wessex Water Plc (WW) supply area fed from Wimbleball lake.

The terms of reference for the study are reproduced at Appendix A. Broad requirements were to:

- review forecasts of public sector water demand in the study area and, where appropriate, assess likely growth in private sector water demand;
- review the present level of resource development in the South West;
- confirm where, and when, shortfalls between drought reliable source yields and forecast demands are likely to occur;
- consider the scope for further resource development or other measures to respond to the forecast shortfalls, and develop a strategy recognising the needs both to respond positively to legitimate demand for water, and to develop resources in an equitable, efficient, and environmentally acceptable manner. The strategy should be as far as possible in line with NRA policies, aims and guidelines.

This report describes the studies carried out in pursuit of these aims, their findings, and a recommended strategy.

1.2 Summary

Data on public sector water demand forecasts were provided by SWWSL and WW. The method by which the forecasts were developed, their sensitivity to parameters and their compatibility with each other and with public sector demand forecasting generally, have been checked. In the case of both companies, it was concluded that realistic forecasts had been produced. The targets for reducing unaccounted for water (ufw) in the SWWSL supply area may be seen as optimistic when compared with published literature, but are accepted. The most critical aspect of the forecasts was identified as the factor applied to reflect seasonal peaking; after careful consideration, values based on the fifteen-year mean from 1976-1990 were chosen.

It has not been possible to forecast private demand with confidence. However, when the exercise is confined to consumptive uses of water, it becomes apparent that spray irrigation is the only private demand where demand growth is significant. If growth in this sector follows the upper bound trend, storage would be needed to support such abstractions. This could be provided either by the abstractors themselves, or by the NRA promoting arrangements whereby a proportion of existing and future reservoir storage could be dedicated to river support for this purpose.

Information on source yields and planned developments was also supplied by the water companies, but it was not possible fully to verify their figures. However, work on past projects in both supply areas suggests that the data provided are realistic.

The problems associated with existing sources include limited flexibility through lack of integration and, in some cases, detrimental environmental impacts. An estimate of the likely cutback in sustainable yield arising from the solution of such environmental problems is 36Ml/d or approximately 6% of the present regional yield.

Based on the perceived likely demand forecast plus a 5% margin for planning purposes, and the water companies' own assessment-of-reliable source yields, peak period deficits in the year 2021 are estimated to be:

- about 152Ml/d in the SWWSL supply area overall;
- about 46Ml/d in the WW Somerset and Avon supply zones.

The planning margin of 5% on demand is included to help provide a buffer against the uncertainties of forecasting, such as a decrease in available resources due to climate change, or an unforseen acceleration in the rate of growth in demand for water. Such a margin is seen as advisable, in view of the long lead time required to bring new water development schemes on stream.

The above figures increase to 208Ml/d and 70Ml/d respectively when allowances are made for a possible shortfall in achievement of leakage targets by SWWSL, and yield cutbacks due to environmental factors in both undertakings' supply areas.

The various means of responding to these deficits which have been considered include:

- conservation measures and demand management (including metering);
- further development of existing resources;
- development of new sources within the study area.

Within the planning horizon (2021), the region is self-sufficient in resources, so there is no perceived need to import water from outside the study area.

In the SWWSL supply area, there is considerable scope to develop existing sources further. Increased source integration, coupled with such further development, forms the basis of the preferred strategy. With or without cutbacks in existing yields, however, an "all-new" scheme may be needed in the SWWSL supply area sometime between 2014 and 2017. With the lower SWWSL area deficit (152 Ml/d), a scheme with a yield of about 25Ml/d would suffice; with the higher deficit (208 Ml/d), a scheme with a yield approaching 100Ml/d would be needed, which could be fully integrated with the SWWSL supply system.

Among the enhancements of existing schemes proposed is the pumped augmentation of both Colliford and Roadford reservoirs, as well as Wimbleball Lake. Augmentation of Colliford and Roadford has not yet been studied, and early work is needed to determine the yield gain that would accrue. Findings of such studies may require the strategy proposed above to be modified.

It is shown that the direct supply to WW from Wimbleball reservoir is inefficient in water resource terms, as it is drawn from the top of the catchment. It is therefore seen as preferable that none of the additonal yield from pumped augmentation at Wimbleball should be shared with WW. Instead, it is suggested that their forecast deficits should be met by further development on the River Avon in the vicinity of Bath. However, it is acknowledged that this solution is not as attractive economically to WW as would be a strategy which allowed them more water from Wimbleball.

It is recommended that the NRA encourage SWWSL to improve their links between different supply zones, thus increasing operational flexibility and making better use of existing resources. This is seen as particularly important in the case of East Devon, where the most pressing operational problems are being experienced. Redevelopment of the Otter valley wellfields should also be pursued, together with pumped augmentation of Wimbleball and related opportunities in the Exe catchment.

It is also recommended that studies into pumped augmentation of Colliford and Roadford should be put in hand as soon as possible.

Long term planning should focus upon identifying options for an all-new scheme. Such planning should also ensure that adequate time is allowed for collecting and analysing relevant data to compare alternative options properly and to assess fully the environmental impact of the preferred scheme.

2 REVIEW OF DEMANDS

2.1 Objectives

Public water demand forecast data were supplied by SWWSL and WW, and reviewed by Halcrow. The objectives of the review were to check:

- that a reasonable and consistent approach has been adopted;

- that the forecasts can be subdivided into appropriate zonal or sub-zonal constituencies to facilitate comparison with individual or groups of existing sources;

- their sensitivity to differing assumptions on leakage control, charging policy, residential/commercial growth patterns and other key parameters.

Private sector forecasts were prepared by Halcrow, using the same methodology recently applied to the national water resources strategy study (1). The principal purpose of the private sector forecast is to give a broad indication of the likely level of commitment of NRA South West Region water resources in the future, for uses other than public supply.

Public water demand forecasts are discussed in Sections 2.4-2.5, and private sector forecasts in Section 2.6. The planning horizon for the forecasts was the year 2021.

2.2 Study Area

The study area is shown on the Frontispiece. It includes the entire NRA South West Region, and that part of Wessex Region supplied with water by bulk transfer from Wimbleball Lake.

The area is predominantly rural, with most of the larger conurbations around the coast, often associated with the estuaries of major river systems (Falmouth, Plymouth and Exeter, for example). The national parks of Exmoor and Dartmoor lie within the region and the extensive coastline and attractive scenery of the area are popular with tourists. Thus tourism is an important component of the local economy, and summer peaks in water demand are relatively high.

Two undertakings are responsible for public water supply and sewage disposal in the study area:

- South West Water Service Ltd (SWWSL), whose entire area is included

- Wessex Water plc (WW), about 7% of whose potable water needs in 1989 were met from Wimbleball lake.

The SWWSL water supply area amounts to 10,300 sq km, and had an estimated connected population of 1,522,000 in 1990. In the case of WW, water from Wimbleball at present meets an estimated public demand of 100,000 people, as well as supplying industries fed from the treated water system, such as Hinkley Point Power Station.

Private demand has only been considered within the South West NRA region, and is made up principally of abstractions for hydro generation, fish farming, industry and agriculture (including spray irrigation). The significance of the WW supply area in the study relates to the bulk transfer from Wimbleball for public water supply; no private demand within NRA Wessex Region is met from resources within the South West. Thus it has not been necessary to forecast private demand within the NRA Wessex region area.

Public and private demand is met mainly through surface water resource development, although groundwater abstracted from the pebble beds/sandstone aquifers underlying the Otter valley and adjacent areas of E. Devon provides some 5% of SWWSL's drought reliable yield.

Rainfall averages from about 800mm/year in the lower Exe area to over 2200 mm/year average over the highest parts of Dartmoor.

For operational resource planning purposes, the SWWSL supply area has been sub-divided into five strategic water supply zones; these are:

- Colliford: most of Cornwall;
- Roadford - N. Devon and Plymouth: effectively the Taw, Torridge and Tamar river catchments;
- Roadford - S.W. Devon: south and east Dartmoor, the South Hams and Torbay areas;
- Wimbleball - Allers and Pynes: the Exe Valley;
- Wimbleball - East Devon: remainder, including Otter and Axe valleys.

Plymouth is occasionally considered separately, creating a sixth zone.

With the exception of parts of East Devon, each zone has a major link with one or other of the three large strategic reservoirs in the area:

- Colliford: Colliford Lake (on Bodmin Moor);
- N. Devon and Plymouth, and S.W. Devon: Roadford Lake (to the north-west of Dartmoor);
- Allers and Pynes: Wimbleball lake (on the Brendon Hills).

Links into East Devon from Allers and Pynes include the East Devon Coastal Main, and the Allers - Honiton Trunk Main. Capacity of these is understood to be limited.

Resources are discussed further in Section 3.2.

2.3 Available Data

2.3.1 General

Public demand forecasting data have been collected from SWWSL and Wessex Water Plc (WW). As the bulk of the analysis relates to the South-West Region, emphasis was placed on the collation of data from SWWSL; capture and analysis of the WW data was less extensive.

Forecasts issued by SWWSL were updated by the Company in September 1991; their review by Halcrow is discussed below.

2.3.2 South West Water Services Ltd

For demand forecasting purposes, SWWSL have divided their supply area into 59 WIS (Water Into Supply) zones. These are small sub-divisions of operational districts and comprise groups of parishes. At present, data are not available on actual demand by WIS zone; the zones therefore remain just a forecasting tool. SWWSL hope to use them as the base unit for resources planning, and are currently installing meters to measure the present level of demand in each. The data collected will then be used to calibrate demand forecasts produced by SWWSL's model. The demand forecasts provided for the purpose of this project were not calibrated against actual historic consumption.

Public water demand forecasts were provided for each WIS zone in the South-West region for the following years:

1991, 1996, 2001, 2006, 2011, 2016 and 2021.

Forecasts of annual average public water demand estimates by individual WIS zone were provided; strategic zone forecasts for the identified years were derived by summation of the WIS zone data. The forecasts included the predicted total demand, and projections for the following components:

- measured demand
- unmeasured domestic demand
- unmeasured non-domestic demand
- unmeasured tourist and miscellaneous demand
- allowance for losses.

In addition to the above, projected total residential population in each WIS zone and the predicted per capita water consumption were provided.

Papers on the forecasting rationale and methodology adopted were also provided. Other information included:

- weekly observed demands for each operational district for the years 1976 to 1990;

- estimates of the connected population for 1989;
- estimates of the projected growth for the main population centres in the South-West to the year 2011; and
- information on the charging policies of SWWSL.

SWWSL use the component analysis method to prepare public water demand forecasts. The technique adopted was developed by Halcrow for the then South West Water Authority in 1987 (2). Pertinent points from that work are described here to clarify the methodology and rationale used. Observed current demand data and short-term forecasts for each component are compared, and the latter suitably adjusted to ensure that a smooth transition occurs between the two.

It is recognised in the adoption of the component analysis that there will always be a degree of uncertainty in the determination and projection of all the many necessary parameters. An envelope of projections is therefore made, with the intention of encompassing a low, likely and high projection. This envelope approach is used to indicate the uncertainty involved in the estimation technique rather than to identify confidence limits.

For the purposes of this study, four components of demand were identified and used in the review of SWWSL and WW data. They are:

- unmetered domestic demand;
- unmetered non-domestic demand;
- metered demand; and
- unaccounted for water.

The unmetered non-domestic component in the SWWSL supply area incorporates the unmetered tourism and miscellaneous demand.

2.3.3 Wessex Water plc

Data provided by WW included graphs showing estimates of the annual average demand for the operational districts. However, the planning horizon of these plots was 2011, and it was therefore necessary to extend these forecasts to the 2021 horizon.

WW also provided a report (3) describing the forecasting technique used; corresponding values presented here have been updated since then. The WW report described the component analysis as applied, and provided data on demand in the following categories:

- metered consumption (10 sub-categories)
- domestic unmeasured demand
- domestic metered demand
- unmetered tourism
- unmetered commercial
- waste.

WW also provided information on their charging policy.

2.4 Existing and Forecast Public Water Demands in the SWWSL Supply Area

2.4.1 Basis of Component Analysis

The SWWSL WIS zones have been combined as appropriate to build up the forecasts for the supply zones of Colliford, Plymouth and North Devon, South West Devon, Allers and Pynes and East Devon, as summarised in Appendix B.

2.4.2 Unmetered Domestic Demand

The proportion of dwellings with metered supplies is very small in the South West, and it has been assumed for the purposes of this study that all domestic demand is unmetered. Unmetered domestic demand is thus taken as the product of the predicted population connected to the public water supply system and their per capita consumption (pcc) of water. Both of these determinands are subject to uncertainty, although the projection of the latter is the subject of greater debate.

The projection of populations is made by Devon and Cornwall County Councils. They use data on the number of births and deaths and the age structure of the community to estimate growth rates of the resident population. In-migration is calculated using a five-year average. These county projections are then broken down into WIS zone forecasts by SWWSL, who use where appropriate any additional local information such as local plans. The projected populations for the main conurbations in the South-West as identified by SWWSL are noted in Table 2.1. Estimates suggest that, at present, approximately 97% of the population is connected to the public water supply system.

It is projected that the population of the South-West will become increasingly concentrated in urban areas, with 44% of the 2011 population in the larger conurbations, compared with about 30% at present. This may mean that the rate of growth in water demand will be smaller than would otherwise be the case, since:

- gardens in urban areas tend to be smaller, so external water use can be lower;
- leakage control in urban areas can be more effective, as the density of connections to the water supply system is higher.

Figure 1 illustrates the predicted population for the strategic supply zones, based on County Council data. The figure shows that rates of growth vary between zones, and from one five year period to the next. The fastest rate of growth and the highest population are forecast in the Colliford zone, whilst the slowest rate of growth and lowest population are forecast by the County Council in the East Devon strategic zone.

Whilst little further can be achieved by the analysis of the population data, this brief review has served to show that temporal and spatial variability exist in them.

In analysing the SWWSL estimates, it was assumed that the connected population would remain 97% for low, likely and high forecasts. However, for the low and high forecasts the product of the per capita consumption and the assumed connected population did not equal the domestic unmetered demand estimates which had been provided.

Such a discrepancy is explained by the method of determining the low, likely and high estimates (2). Low, likely and high estimates for each parameter are made, and the forecasting model computes a full matrix of potential solutions. These solutions are then ranked and low, likely and high forecasts selected; such forecasts are usually not at the extremities of the ranking but part way through. Thus, the selected high domestic unmetered demand forecast is not necessarily associated with the high population estimate.

The second component of unmetered domestic demand is the predicted per capita consumption (pcc). SWWSL have adopted the values shown in Table 2.2 for all operational districts and for all WIS zones. No distinction has been made between predominantly urban or rural areas.

The estimation of projected pcc, as noted earlier, is the subject of much debate and is also inherently difficult to estimate. SWWSL established their metering trials in 1977 when 1000 households were studied, including a detailed assessment of water use patterns. Local meters have since been read at 6 monthly intervals, and the detailed study was updated in 1983; it provides valuable information on appliance ownership, pattern of use and typical water consumption per cycle, as well as estimates of the proportion of domestic demand which is represented by garden watering and other activity outside the house. The most recent survey put present usage at about 3%; on a seasonal basis, the proportion will be larger, as it mostly comprises garden watering.

In order to estimate the pcc growth rate, the then South West Water Authority investigated the potential for growth in the ownership of domestic appliances. That work was updated in 1987 by Halcrow, when the appliance usage survey was reviewed. The pcc forecasting method involves projecting the use of water for:

- baths;
- showers;
- hand basins;
- toilets;
- washing machines;
- dishwashers; and
- waste disposal units.

Growth in the ownership and the volumes of water used by the appliances were estimated by discussion with manufacturers. The demand for water to be used outside the house has been assumed to grow in proportion to the internal domestic components. Bearing in mind the relatively small proportion of overall domestic use which outside watering represents, this is seen as acceptable for present purposes.

The rates of growth in pcc adopted by SWWSL show a slight decline with time, being +0.9% per annum between 1991-1996, and +0.8% per annum between 2016-2021. It has been argued that a more dramatic slowing could occur, associated with the saturation of the market with domestic appliances. Another argument could be that a change in the charging policy, which must occur by the year 2000, could cause a reduction in demand if it involves a system more closely allied to water usage than at present (eg metering).

It must also be remembered that, whilst in the SWWSL component model domestic unmetered demand is the product of population and pcc, the relationship also involves household size. Social and demographic changes are leading to a decrease in the number of occupants in each household; such changes may cause an overall increase in the number of appliances bought and hence an increase in demand. SWWSL's model does not make predictions on changes in occupancy rates.

Given the uncertainties involved in the estimation of projected per capita consumption, there seems little justification for adjustment of the data provided. However, for the purposes of comparison, pcc forecasts adopted by other water supply companies are presented in Table 2.3. It is seen that most estimates of pcc lie in the range of 140-160 l/c/d in 1991 and 170-190 l/c/d in 2011. The SWWSL "likely" figures of 141 l/c/d in 1991 and 167 l/c/d in 2011 may thus be seen as modest but unexceptionable.

Figures 2a - 2g illustrate the predicted unmetered domestic demand for the strategic supply zones in the SWWSL supply area for the years 1991 to 2021. Unmetered domestic demand accounts for between 40% - 52% (according to assumptions made about demand growth rate - low, likely or high - and leakage) of total demand at the end of the planning period, compared with about 42% at present.

2.4.3 Unmetered Non-Domestic Demand

This component of demand incorporates a range of uses such as fire-fighting, mains-flushing and any unmetered business premises. In the SWWSL forecasts, the component is relatively small, accounting for approximately 6% to 8% of total demands. SWWSL argue that this is because of their policy for metering all business premises in the region; the policy includes all hotels and self-catering holiday homes. Discussions with SWWSL suggested that all major business premises are already metered.

Figures 2a - 2g illustrate the SWWSL projection for unmetered non-domestic demand for all strategic zones through to the year 2021. The figure shows an increase in the absolute amounts of water demanded, although the relative amounts, in comparison with total demand, remain constant. The projections are, therefore, consistent with SWWSL's stated position with respect to the metering of business premises.

2.4.4 Metered Demand

As noted above, it is SWWSL policy to meter all business premises. The metered component of demand is, therefore, of great importance and in general accounts for 27% of total demand in the South-West. The SWWSL forecasts do not break metered demand into any sub-components, although clearly many parameters are utilised in its estimation. These parameters are used in a multiple-linear regression analysis with metered demands as dependent variables and the parameters as the independent variables.

The parameters used are economic indicators including indices of:

- industrial production;
- retail price;
- agricultural production;
- tourism;
- number of meters;
- cost of water.

The index of industrial production is published in the 'Annual Abstract of Statistics', from the Central Statistical Office (4). It is a national index representative of all industrial sectors. The retail price index was introduced primarily as an indicator for the discounted cost of water, although it was treated as an additional independent variable. The latter statistic was also obtained from the 'Annual Abstract of Statistics'.

The index of agricultural production was obtained by time series analysis of statistics produced by the Agricultural Economics Unit at the University of Exeter. The index of tourism was compiled using data from the Devon and Cornwall County Councils. Data on the total number of tourist-nights and the type of accommodation occupied were provided, and adjusted to calculate an annual rate of tourism.

Time series analysis was also applied to the number of meters in use. Although this parameter is still included, SWWSL's policy of ensuring that all new or major business premises are metered will have some impact on the current nature of the time series.

The parameter values used in the multiple index linear regression analysis (MILRA) model were reviewed by Halcrow in 1987 as part of the Settlement Studies. SWWSL have not updated them since; this is not seen as significant since constants are applied to these indices in the MILRA in order to fit the projected demand curve to the historic demand curve. If the indices were to be updated, the MILRA would also need to be reviewed and new constants deduced, with the same objective of fitting the projected to the historic demand curve. As significant trend departures since 1987 have not been noted, this exercise is not justified.

Figures 2a - 2g illustrate the projected metered demand for the six strategic zones through to the planning horizon of 2021. The figures show a growth in metered consumption, although the proportion of total demand which it represents remains constant in all of the districts.

During the forecasting period 1991-2001, all zones show a small overall increase in demand except for South-West Devon, where it remains constant; the fastest increase in demand occurs in Colliford and North Devon, where in the period 2001-2011, an increase of 1.8 % per annum is predicted.

2.4.5 Unaccounted For Water and Leakage Control Policy

Analysis elsewhere (1) has shown that unaccounted for water (UFW) in the SWWSL supply area amounted to approximately 29% of total demand in 1990. It is clearly difficult to estimate the volume of losses in a system, especially given the uncertainties in estimating the volumes of demand in other categories.

The technique used by SWWSL to estimate UFW is night time drop tests at service reservoirs. These are conducted by identifying a contained demand area, and closing off the inflows to the system. Consumers with measured supplies have their meters read at the start and finish of the test period. Net night flow is then deduced through consideration of the volume of water represented by the drop in reservoir level, less metered consumption during the test and a small allowance for legitimate night usage (SWWSL use 2 l/prop/hour). Clearly, by conducting the tests at night, demand - and in particular unmetered demand - is limited.

Whilst drop-tests do give the best available value of UFW in a system at a particular time, they are only an estimate. Inaccuracies occur due to the limitations of meters measuring the volume supplied to a particular system, and the difficulty of estimating legitimate night use.

Given the large capital costs of developing new resources, SWWSL have identified the economic importance of controlling leakage. Thus a leakage control programme is inherent in the demand forecasts produced by SWWSL. This programme has been implemented in the former Fowey, Taw, Dart and Exe operational districts and, in late 1991, was in the process of being implemented in Fal and Tamar. Leakage control targets have been set for these districts, and are to be met by 1996. The leakage control policy in the Exe district was reviewed in 1991, with the forecast leakage saving being revaluated downward. Leakage control targets in all districts are now also under review, but revised figures were not available at the time of this study.

Figures 3a - 3g illustrate the total demand predictions for the strategic zones, with and without leakage control. The impact of the leakage control programmes can be clearly seen in the reduction of overall demand in 1996 in comparison with 1991. Overall, SWWSL are attempting to reduce the UFW from 29% to 16% of total demands. The most ambitious UFW control programmes are in the Colliford and North Devon zones, where a UFW of 27% in 1991 is to be reduced to 13% by 1996.

Whilst a 16% UFW may be a stringent but achievable target, it is anticipated that SWWSL may have some difficulty in achieving it by 1996. In addition, the incentives to reduce UFW are greatest when resource development expenditure can be delayed in the relatively short-term. In the period 1991-1996 the development of Roadford Reservoir, which helps to meet the needs of North Devon, will mean that the financial benefits of vigorous leakage control in that area will not be as great as would be the case if available resources barely matched current demands.

The issue of leakage control is discussed further in Section 4.3.2.

2.4.6 Peaking Factors

All of the above analysis and discussion has used annual average predictions of demand. Whilst these encompass low, likely and high demand predictions, they do not give any indication of the likely magnitude or timing of any peaks in demand.

The concept of peaking factors is an essential and yet difficult component of demand forecasting to analyse and interpret for resource planning studies. Clearly, sufficient resources need to be available to meet seasonal peaks in demand as well as the annual average.

The relative importance of the peak demand will depend not only on the size of the peak, but also on the type of resources available to meet the peak. A resources system consisting of large reservoirs will be able to meet peak demands more easily than one comprising of run-of-river abstractions. Also, as local peak demand periods do not all occur at the same time across the region, they can more easily be met if the water resources of the region are well integrated. The location and timing of peaks are therefore important and are discussed further in later chapters of this report; the identification and selection of peaking factors are considered below.

Demand profiles for the SWWSL supply area and for the six operational districts have been compiled for the years 1976-1990. From these, the peak week demand has been extracted for each operational district and for the whole region, for each of the available years. These values were then divided by the appropriate annual average demand to generate one week peaking factors, shown diagrammatically in the form of box-plots in Figure 4. The boxplots illustrate the wide range of peaking factors from district to district and between years. It is important to note, however, that the peaking factor is reduced by the imposition of drought orders and hose pipe bans, such that the driest year does not necessarily have the highest peaking factor.

Figure 4 shows a maximum one-week peaking factor of 1.41. The usefulness of this factor in the planning of water resources is limited. Such high peaking factors, if used in resources planning, would generate a situation where large resources were developed in order to meet a very extreme set of circumstances.

The mean one-week peaking factor shown on Figure 4 for the SWWSL supply area is about 1.16. This compares with the four-week peaking factor for the area of 1.11 used in analyses in Chapters 4 and 5 of this report.

The four-week peaking factor is seen as a more useful factor in resource planning terms. The source yields provided by SWWSL are understood generally to be based upon sustainable output during a four-week peak demand period (see also Section 3). The four-week peak is here defined as a period of four consecutive weeks, over which the average rate of demand is higher than the corresponding figure for any other four-week period in the year. It is therefore theoretically possible for the four-week period not to encompass the overall one-week peak, although in most cases this is unlikely to happen.

The four-week peaking factors have been extracted from the 1976-1990 demand profiles and are shown in Table 2.4. Also noted are the date, as a week number, of the commencement of the four-week period. Table 2.4 illustrates a range of peaking factors from 1.04 to 1.38, which as expected, is a rather less than the peak week range. However, it is important to note the range of dates for the four-week period, which is rather larger than expected, all districts being similar climatically. It may be, however, that such a range is indicative of the population density, and that there is an urban/rural dichotomy in peak demand.

The peaking factors described above, however, still overestimate the true regional peak. This is because applying the appropriate peaking factors throughout the region implies that all the district peaks occur at the same time. This would describe a potential worst-case scenario, since inspection of Table 2.4 shows that no peaks have coincided exactly over the period 1976-1990, although there has often been a significant overlap.

Because of this difficulty in the timing of the various district four-week peaks, a new definition has been used, and the peaking factors recalculated. The definition involves re-analysing the demand data in order to identify the four-week period for which the majority of the districts have the highest demand. This is of course reflected in the date of the regional peak, although it is not necessarily the same. These new four-week peaking factors are reported in Table 2.5, which also shows the date of the commencement of the identified four-week period. This definition ensures that the regional peak demand is reflected in the district peaking factors.

Table 2.5 shows that there is a range of peaking factors from 0.96 to 1.34. There does not seem to be any particular pattern or trend in the data, for example the operational district factors do not all increase in any one year. Such an occurrence could be associated with a particularly dry year for example. The variability could of course be associated with differing demand management strategies or the differing demand pattern between districts, but is more likely related to the rainfall pattern in a particular year in May/June, when most peaks occur. For the purposes of this study, therefore, it has been accepted that the peaking factor can be seen as random.

Given a random distribution, selection of any one particular value or set of values for the investigation of resources planning is difficult. This issue is further discussed in Section 2.4.7 below.

2.4.7 Overall SWWSL Supply Area Demand Projection

The previous sections have explored the methodology and rationale behind the forecasting technique adopted by SWWSL, and have investigated the variability in the magnitude of each component for each district and throughout the planning period. The analysis has shown overall that a logical and robust approach has been adopted. Any shortcomings have been identified but insufficient data are available to suggest more feasible explanations or alternatives.

The "likely" average annual public water supply demand forecasts are presented by strategic zone in Table 2.6. Adopting the preferred "likely" demand forecast, overall growth in the SWWSL supply area is equivalent to about 1% p.a. over the 1991-2021 planning horizon.

The sensitivity of the demand forecasts to variability in the parameters used has been examined. The most significant parameter is the peaking factor. This scales the regional forecast by a factor of anything between 1.07 and 1.19, and in comparison with other parameters has the greatest impact on the overall magnitude of the demand.

In describing the various other components of SWWSL's demand forecasts, general satisfaction has been expressed in the methodology and rationale applied. In the estimation of metered demand, however, many of the indices used have not been recently updated and some uncertainty must therefore attach to the index values applied. Similarly, uncertainty may occur with the values of per capita consumption (pcc). However, modification of these components is not explored further, as analysis has shown that the overall prediction is rather insensitive to these issues. A slowing of the growth of pcc towards the end of the planning period will indeed cause a change in slope of the demand curve, but the overall magnitude of the curve is determined to a much larger extent by the selected peaking factor.

The selection of an appropriate peaking factor is a subject of much debate. No particular pattern or trend in the South-West data can be identified to guide this selection.

After careful consideration, a decision was made to use the mean value of the operational districts peaking factors recorded between 1976-1990. The choice was made on the grounds of simplicity and robustness, and reflected the limited data set available. The mean included the entries from the four drought years of 1976, 1984, 1989, 1990; it may be argued that these peaking factors are unrepresentative, since demand may have been suppressed by a resource shortfall and by publicity campaigns to reduce demand. However, this was not believed to be a key factor in the South West, since peak demands typically occur in late May/early June, before the rainfall deficit pattern (which a drought entails) has become apparent. It was only when the lack of rain persisted through June and into July 1989 that drought measures were introduced.

Selection of the highest peaking factor was believed to be misleading, since to compare the highest historic peaks in demand with the lowest resource availability is to combine two low-probability events; the likelihood of their conciding must be significantly less than the 2% nominal risk conventionally applied to water resource planning.

In addition, earlier discussion has highlighted the downward influence on peaking factors as districts are integrated. The trend to integration has been given a significant boost recently with the commissioning of the trunk main linking the Roadford system with South West Devon. This trend is likely to continue.

In the light of these considerations, the use of the mean value of peaking factors between the years 1976-1990 is seen as realistic for the purposes of the present study. The chosen values for the new strategic zones, and the corresponding "likely" peak 4-week SWWSL demand forecasts, are set out in Table 2.7, and summarised below:

Strategic Supply Zone	Peaking Factor	Forecast Peak 4-Week Demands Ml/d 1991	2011	2021
Colliford	1.15	171	212	248
N Devon	1.07	75	90	105
Plymouth	1.07	97	119	133
S W Devon	1.19	108	122	139
Allers & Pynes	1.06	62	76	86
E Devon	1.15	42	49	56
Region	1.11	550	662	760

These figures have been adapted from peaking factor values for the old operational districts. A detailed description of how the data were converted is given in Appendix B.

2.5 Existing and Forecast Public Water Demands in the WW Supply Area

2.5.1 Overview

Analysis of the demands of WW supply area has concentrated on the potential impact of Wessex demands on the South-West Region. This impact is restricted to potential demands on Wimbleball Reservoir. The objective of investigating the demand curves of Wessex is to ensure that a reasonable approach has been adopted, and that a common basis of comparison between the South-West and Wessex is established.

Wessex Water Plc adopt a different overall demand forecasting methodology to SWWSL. The technique used is a combination of extrapolation for short-term forecasts (the next five years), and component analysis for longer planning horizons. To ensure that there is not discontinuity in the projected demand curves, the component analysis is adjusted to match the extrapolated forecast. As noted earlier, the planning horizon adopted by Wessex is 2011; this has been extended to 2021 as described in Section 2.5.7.

Due to recent changes and privatisation of the water supply industry, changes have been made to the districts in Wessex used for demand forecasting. Prior to privatisation, several supply districts are identified in the Wessex Water Authority (WWA) report 'Review of consumption forecasts for potable water supply, 1986-2011' (3). These districts are shown on Figure 5 and were supplied by five companies. WWA supplied three zones, namely: the Avon and Dorset Division, Bristol Avon Division and Somerset Division.

The privatised Wessex Water Plc, for the purposes of demand prediction, have reviewed the sub-division of their supply area and now use four districts:

- Somerset;
- Avon and Wiltshire;
- Dorset;
- Salisbury.

The Avon and Somerset districts are integrated; however neither have strong connections with the Dorset and Salisbury districts. As interest in Wessex Region is centred on the Wimbleball supply area, the Dorset and Salisbury districts are not included in the analysis for this report. Data are available using sets of both supply zones and of districts, and an attempt to integrate these two sets has been made.

In the following sections, the component analysis is investigated and comparisons made with SWWSL's forecasts. It should be noted that the components used by WW do not match those used in this analysis and therefore some interpretation of their relative magnitude has been necessary. The convolution of extrapolation and component analyses is discussed further in Section 2.5.8.

2.5.2 Unmetered Domestic Demand

The Wessex method of estimating the unmetered domestic component of demand is similar to that adopted by SWWSL, in that it is the product of population projections and the per capita consumption.

Population estimates are made using a trend analysis of historic data from the office of Population Censuses and Surveys. For Avon, this includes adjusted predictions from the County Council until 1996; projections beyond this period were made by WWA. For Somerset, County Council estimates are available for 1991 and 2001; WWA then interpolated a value for 1996 and extrapolated to obtain a value for 2011. The relevant population data presented in the 1986 WWA report are reproduced here as Table 2.8.

For all districts, the data illustrate that a decrease in the rate of population growth is expected during the planning period.

Levels of per capita consumption in 1986 were estimated on the basis of a trial including some 59 small groups of houses, containing a total of 1406 dwellings. In Avon, 750 houses were monitored in 35 groups; this study generated an estimated value for per capita demand of 155 l/c/d. In Bristol Avon only 90 houses were monitored and this number was considered insufficient to estimate per capita demand reliably. In Somerset, 566 houses in 19 groups were monitored; this study gave an estimated per capita demand of 139 l/c/d. These data were collated divisionally and related to the rateable value of the houses following a Severn-Trent Water Authority study of the Malvern and Mansfield areas. The above quoted 1986 pcc values may be compared with the 1991 range of 140-160 l/c/d deduced from Table 2.3

WWA's technique for forecasting growth in pcc is believed to have been broadly similar to that developed by Halcrow for the then SWWA and applied in the Settlement Studies (2) and Wimbleball Lake demand forecast (5), also carried out in 1986 for WWA and SWWA.

It may thus be expected that at least the rate of growth in per capita demand should be similar for SWWSL and WW estimates. Table 2.9 shows how forecast pcc varies across the Wessex supply area. This variability is relatively large. Comparison of the rates of growth between SWWSL and the relevant WW zones shows that in Somerset and Avon the growth rate for 1991-2001 is +0.9%/year, identical to SWWSL. However, for the period 2001-2011, estimates for Somerset are +0.7%/year, and for Avon +0.6%/year; SWWSL's estimate is for a rate of +0.8%/year. This difference may be explained by the calibration adjustments made by both the undertakings.

Since the WWA report of 1986, however, Wessex Water have provided new projections of the total demand. Although the component analysis behind these forecasts is not available, it is noteworthy that overall Wessex Water estimates are significantly higher than those contained in the WWA report.

Estimates for 1991 total demand have been adjusted from 121 to 128 Ml/d, for 2001 from 141 to 151 Ml/d and for 2011 from 153 to 163 Ml/d.

The per capita consumptions associated with WW estimates have been deduced in Table 2.10, assuming for the moment that WW population estimates are correct and that the relative proportion of demand for each of the identified components remains constant.

These figures are significantly higher than the corresponding values shown in Table 2.9, and serve to show that the assumption of unadjusted population estimation is flawed. However, this computation does show that the adjustment in population estimates between the WWA 1986 report (3) and the data provided in 1991 is relatively large.

2.5.3 Unmetered Non-Domestic Demand

In the WWA projection, this category contains some tourist, commercial, firefighting and mains flushing demands, and accounts for a relatively small proportion of total demand (approximately 7%). It is interesting to note that this figure is similar to that of SWWSL's, despite the latter's stated policy of metering all businesses, including tourist demands.

2.5.4 Metered Demand

In the WWA forecast, metered demand has been sub-divided into a great many components which include:

- metered domestic
- metered tourism
- agriculture, horticulture etc.
- industry
- commerce
- local authority (schools, hospitals, etc.)
- defence
- public water supply (metered)
- power generation
- miscellaneous

The growth in each of these components has been separately estimated. For example, a growth rate of +4.9% per annum has been used from the British Tourist Authority, Tourism Fact Sheets, West Country, 1984. For industrial growth, seven categories are disaggregated from the billing records and the Cambridge Econometrics model applied. Insofar as this applies economic prospects of the various commercial and industrial sectors to forecasting, rather than extrapolation of past trends, the approach is similar to that used by SWWSL (see Section 2.4.4).

2.5.5 Unaccounted for Water (UFW)

Unaccounted for water represents approximately 13 % of demand in Somerset and 18 % in Avon in the WWA forecast for 1991. In Somerset this proportion remains constant throughout the planning period. In Avon, however, a leakage control strategy is introduced to reduce leakage to 14% by 2011. These projections of 1991 leakage are small in comparison with the corresponding SWWSL estimates. This may reflect the higher level of investment in leakage control by WW, or incorporation of a part of this demand elsewhere in the estimates. Areas of uncertainty, as with the SWWSL forecasts, are the domestic un-metered demand and the non-domestic un-metered demand. However, given the lack of up to date information on the Wessex component analysis, this line of investigation could not be pursued further. For the purposes of the analysis, it has been assumed that WW achieve their stated level of leakage control.

2.5.6 Peaking Factors

Data were not made available to analyse peaking factors from historic demand data. In the WWA report, the maximum historic peak week factors are identified. These are 1.28 for Somerset and 1.3 for Avon. On their more recent resource planning graphs, WW apparantly match peak source output to about 1.25 x forecast demand, but make no other provision for a planning margin. For the purposes of this investigation, given the difficulties of estimating a peak factor, a figure of 1.15 has been applied to both Avon and Somerset demands. This equates with the Colliford zone fifteen year mean peaking factor from 1976-1990, the second highest in the SWWSL supply area after South West Devon. Use of this factor is seen as conservative, since:

- the upward influence of tourism on peaking factors is likely to be more marked in Cornwall than in Avon/Somerset;
- sources in Avon/Somerset are well integrated, which tends to reduce peaking factors in the overall system.

2.5.7 Extrapolation of Wessex Demands

As noted earlier, the demand horizon currently used by Wessex Water Plc is 2011. In order to facilitate comparison between the South-West and Wessex regions, and to enable the resource development strategies to be fully explored, the demand horizon for the WW supply area needs to be extrapolated to 2021.

As data were not available to undertake a component analysis for the Wessex supply area, an extrapolation technique was used. Two approaches were adopted, which provide high and low forecasts for Somerset and Avon. These were:

(a) simple extrapolation using the average annual rate of growth as is forecast for the period 2001-2011;

(b) complex extrapolation by fitting a curve to the 2001-2011 forecast.

Somerset Demands in 2021

Rates of demand reflected in the WW forecasts for Somerset are shown in Table 2.10. When the deduced demand growth is plotted against time, the resulting curve may be approximately expressed by the relationship:

(1) $D_{sn} = 118 + 33.23 \log n$

where D_{sn} is the Somerset demand in Ml/d n years from 1990.

Applying the two approaches to obtain a 2021 forecast demand for Somerset gives values as follows:

- 176 Ml/d using method (a), with annual growth rates of 1.008 (as 2001-2011); a 'high' forecast;
- 168 Ml/d using method (b) and equation (1); a 'low' forecast

Avon Demands in 2021

Rates of demand reflected in the WW forecasts for Avon are shown in Table 2.11. By similar analysis, the growth curve expression for Avon is:

(2) $D_{an} = 110 + 17.17 \log n$

2021 forecasts for Avon thus become:

- 146 Ml/d High (method (a) annual growth rate 1.007)
- 136 Ml/d Low (method (b), equation (2))

The analyses were supplied to Wessex Water Plc for approval and comment. The methodology was approved but the following recommendations were made on the selection of high, likely and low forecasts that:

- the above high forecast should be made the likely forecast; and
- the high forecast should be a mirror image of the low forecast reflected in the new likely forecast.

These recommendations increase the likely average annual 2021 forecasts by just under 6%. On the basis of WW's advice, they were adopted and the new high, likely and low forecasts for Avon and Somerset are shown in Table 2.12 and on Figure 6. This figure also shows that high and low forecasts were not available for the years 1991 to 2011.

2.5.8 Overall Projections

The demand curves for the Somerset and Avon districts are shown on Figure 6. These are likely average annual projections. They combine extrapolation and component analysis, and the discontinuity in the rate of predicted growth of demand between the two methodologies is clearly visible. The extrapolation technique projects a much more rapid rate of growth than the component analyses. Given the relative large adjustments required to the component analysis conducted in 1985/6 it could be argued that, at least for the Wessex supply area in the near future, the extrapolation technique seems to be most appropriate.

The change in demand over the planning period 1991-2021 for Avon and Somerset forecast to be:

	Average Annual		:	4-Week Peak (PF = 1.15)	
	1991	2021	:	1991	2021
• likely:	242	322	:	278	370 Ml/d
• low:		304	:		350 Ml/d
• high:		340	:		391 Ml/d

Over the planning period 1991-2021, demand growth in Avon/Somerset is equivalent to approximately 1% per year. This is similar to that forecast in the SWWSL supply area.

2.6 Existing and Forecast Private Demands

2.6.1 General

Private demand in Wessex supply area has not been addressed, since it is not met by Wimbleball Lake.

Data on licensed daily abstractions in the South West Region were extracted from a summary of licences produced in November 1991 by the NRA, and are presented in Table 2.13.

Fish farming and hydropower generation have been excluded from Table 2.13, because generally all the abstracted water is returned locally and is thus available for re-use. A notable exception is the Morwellham power station abstraction from the River Tavy at Abbey Weir, Tavistock, which diverts water into the River Tamar. The resource implications of this are reflected in the conditions governing the public water supply abstraction at Lopwell dam, the tidal limit of the Tavy.

Detailed breakdowns of daily licensed abstractions by river catchment in each supply zone are given in Appendix C.

The purpose types are incorporated in the following categories of abstractions:

Category and Net Consumptive Use (%)		Purpose
Spray Irrigation	-	Agriculture
100%	-	Municipal (sports facilities, dust suppression etc)
Agriculture 30%	-	General (excluding pisciculture)
Industrial processing	-	Power industry (boiler feed)
30%	-	Quarrying
	-	Food and Drink
	-	Miscellaneous

Other purpose types exist, such as industrial cooling and pisciculture, but have a net consumptive use of 0%. The effect on available resources is thus very localised (between the point of abstraction and the point of return to the river system) so they have been ignored for the purposes of this study.

The resource planning implications for each of the above demand types are outlined below.

2.6.2 Spray Irrigation

The water demand for spray irrigation occurs predominately during the summer months in order to increase crop yields. Demand is at its greatest during drought years when water resources are at their lowest.

When considering the resource implications of existing spray irrigation demands, the following points and forecast should be noted:

- the distribution of spray irrigation licenses in the region is very localised, with over 40% occurring in Allers and Pynes and East Devon supply zones combined, and 33% in Colliford supply zone (over 13% are located in the River Hayle and Red River catchments);

- in terms of maximum daily demands, 70% of the water is taken from surface sources (watercourse and storage areas) while 30% is taken from groundwater sources. During drought conditions, when demand will be at its greatest, the immediate effect of abstraction from groundwater will not be as marked as from watercourses.

Forecasts of spray irrigation growth in the Region (Table 2.14) are based upon an upper bound growth rate of 4% and a lower bound of 1%. These values were chosen following a review of national historical trends and literature survey (1). In the absence of reliable information to the contrary, an uptake of 100% of licensed entitlement has been assumed in preparing

Table 2.14. The experience in Anglian Region (1) suggests a lower figure (60-70%) may be appropriate there; however hydrogeological conditions are very different in that Region.

The upper forecast predicts a possible trebling of daily (ie peak) demand by the year 2021; this demand is concentrated in areas where water resources are already scarce in dry summers. However, the irrigation season is only of a few months duration, so that annual abstractions are relatively modest. Because of its potential impact on dry weather flows, it is clear that licensing of irrigation needs to be kept under close review. In many cases, flow protection requirements may necessitate confining abstraction to the winter months, when available surface flows are greater, which would entail provision of storage by the license holder. The issue of abstraction licensing in relation to resource management is discussed further in Section 4.2.2.

2.6.3 Agriculture

The total daily agriculture licensed abstraction volume in the region is 32.5Ml/d. With the exception of slightly higher levels in Allers and Pynes, abstraction volumes are relatively evenly spread between the supply zones.

There are many uses for water in agriculture, but the principal demands arise from the consumption of water by livestock and for dairy purposes. Abstractions for pisciculture have purposely been excluded from this category, since the large quantities involved hide the true agriculture demand level.

It is important to remember that agricultural abstractions of less than $20m^3/d$ (0.02 Ml/d) are exempt from licensing control if taken from a surface water source on, or adjacent to, the farmer's own land. Moreover agricultural abstractions from groundwater in certain parts of North, Central and South Devon are exempt from licensing. The implications of these exemptions are not known, although the one relating to groundwater was introduced on the premise that its impact on available resources would be slight. The potentially large number of these small abstractions that do not require licenses may help to explain why the total licensed volume of agricultural abstraction seems low in relation to the regional importance of this industry.

Some 99% of licensed abstraction for agriculture is from groundwater sources; this probably reflects the farmers' requirement for a reliable and clean source of water throughout the year, as well as absence of convenient surface water sources on many holdings.

A review of the national historical agriculture demand (1979-1990) showed a general decline but did not reveal a definite pattern (1). A range of +/-1% growth rate was therefore used to estimate the upper and lower bounds of agricultural demands in the future (Table 2.15). These are again based on an assumed 100% uptake of licensed quantities.

The upper bound forecasts predicts a regional increase in agricultural demand of 11.3Ml/d. This is not seen as particularly significant, particularly if it is borne in mind that net use of water for agriculture is only 30% of this figure.

2.6.4 Industrial Processing

A substantial proportion of industrial abstraction is to be found in the large towns such as Plymouth (13%) and Exeter (10%). There is a considerable demand in the St Austell area and the River Fal catchment associated with the activities of the china clay industry. Daily abstraction licences in these areas total 81.9Ml/d, or 40% of the total region's licenced quantity. The abstractions are largely from groundwater and are believed to be mainly for processing purposes.

The summary of industrial processing daily licensed abstraction excludes licences dedicated to water power. Water power facilities require vast amounts of water, but neither consume water nor reduce water quality and their inclusion would therefore mask the real consumptive demand growth trends.

A review of total industrial process demands in England and Wales over the period 1979-1990 (1) did not reveal any definite trend, although a general decline in demand was observed. A range of +/- 1% growth rate was therefore taken to estimate the upper and lower bound forecasts given in Table 2.16.

The upper bound forecast predicts a 35% increase in industrial processing demand, from 202Ml/d in 1991 to 272Ml/d in 2021, assuming 100% uptake of entitlement. In terms of net use, this upper demand increase amounts to 21Ml/d.

2.6.5 Overview of Private Licensed Abstraction Growth

The data set out in Tables 2.14-2.16 are summarised below:

Purpose	Daily Authorised Quantities (Ml/d)			Change in consumptive use over period (Ml/d)	
	1991	2021 lowerbound	2021 upperbound	2021 lowerbound	2021 upperbound
Irrigation	85	115	277	30	192
Agriculture	32	24	44	-2	+4
Industrial Processing	202	149	272	-16	+21
Totals	329	288	593	+12	+217

TABLE 2.1 1989 Population Estimates and 2011 Forecasts For Main Conurbations in the SWWSL Supply Area

	1989 estimate	2011 Forecast	
		Low	High
Plymouth	255000	278700	281500
Torbay	120100	131900	134400
Exeter	102300	105900	106700
Exmouth	31400	34800	37400
Newton Abbot	23200	26900	28000
Barnstable	22300	26800	30900
Penzance	21300	24700	25700
St Austell	20200	27400	29200
Cambourne	19000	25000	26400
Falmouth	18000	23400	24700
Tiverton	17700	22300	25200
Truro	16400	25100	27200
Newquay	16300	20200	21200
TOTAL	683200	773100	798500

TABLE 2.2 Low, Likely and High Per Capita Consumption Forecasts For SWWSL Supply Area

Planning horizon	Per Capita Demand (l/c/d)		
	Low	Likely	High
1991	137.5	140.7	143.9
1996	140.7	147.1	153.6
2001	143.7	153.5	163.3
2006	147.0	159.9	173.5
2011	150.0	166.5	183.4
2016	153.3	173.0	194.0
2021	156.7	179.7	204.8

TABLE 2.3 Comparison of Projected Per Capita Demand For Various Water Supply Companies

(from Water Resources Planning - Strategic Options, Vol 2, Annex B, Table B6, Halcrow 1991)

Water Company	Per Capita Demand (l/c/d)		
	1991	2001	2011
Anglian	140	150	180
Cambridge	150	170	185
Essex	140	162	179
Suffolk	142	157	172
Tendring	136	156	176
Eastbourne	174	189	209
Folkestone	158	174	193
Mid Kent	155	172	190
Mid Sussex	162	179	197
Portsmouth	156	172	190
Southern	148	173	192
West Kent	159	176	194
East Surrey	151	169	190
Mid Southern	144	162	189
North Surrey	150	166	184
Sutton	148	163	173
Thames	144	105	182
Three Valleys	150	176	173
Chester	130	142	156
Dŵr Cymru	142	160	165
Wrexham	139	151	165
Yorkshire	126	136	146

TABLE 2.4 4-Week Peak To Annual Average Demand Ratio By SWWSL Operational District, 1976-1990

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Max	Mean
Fal	1.19	1.17	1.12	1.15	1.09	1.20	1.13	1.18	1.09	1.11	1.10	1.15	1.10	1.16	1.11	1.2	1.14
Fowey	1.38	1.28	1.18	1.23	1.18	1.27	1.23	1.22	1.12	1.15	1.16	1.18	1.16	1.19	1.21	1.38	1.21
Tamar	1.11	1.05	1.07	1.12	1.05	1.10	1.06	1.12	1.09	1.07	1.08	1.06	1.04	1.04	1.06	1.12	1.07
Taw	1.22	1.13	1.08	1.18	1.08	1.16	1.10	1.17	1.09	1.06	1.04	1.10	1.07	1.13	1.12	1.22	1.12
Dart	1.21	1.29	1.18	1.34	1.18	1.29	1.24	1.25	1.16	1.15	1.15	1.18	1.13	1.16	1.11	1.34	1.20
Exe	1.13	1.13	1.10	1.15	1.10	1.09	1.05	1.10	1.15	1.08	1.08	1.08	1.12	1.10	1.10	1.15	1.10
Week Number At Commencement Of Four-Week Peak Demand																	
Fal	25	30	29	27	30	33	29	30	24	27	30	31	28	28	29		
Fowey	27	30	29	28	31	33	33	30	26	27	28	32	29	24	27		
Tamar	5	27	21	27	1	33	29	27	24	30	27	3	17	22	28		
Taw	29	27	22	27	33	33	29	31	26	27	9	33	31	28	29		
Dart	30	29	32	27	30	31	29	27	24	27	29	32	24	22	29		
Exe	23	30	22	27	20	27	22	27	25	6	28	28	23	24	29		
Region	25	30	22	27	30	33	29	27	24	27	29	32	24	24	29		

TABLE 2.5 4-Week Peak To Annual Average Demand Ratio By Operational District, 1976-1990 For Specified Period

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Fal	1.19	1.17	1.10	1.15	1.09	1.20	1.13	1.17	1.09	1.11	1.10	1.13	1.08	1.10	1.11
Fowey	1.12	1.28	1.15	1.23	1.16	1.27	1.15	1.19	1.11	1.15	1.17	1.18	1.11	1.19	1.18
Tamar	1.03	1.04	1.06	1.12	1.00	1.10	1.06	1.12	1.09	1.07	1.01	0.96	1.04	1.05	1.12
Taw	1.13	1.11	1.08	1.18	1.06	1.16	1.10	1.15	1.09	1.06	1.04	1.09	1.02	1.13	1.07
Dart	1.19	1.29	1.12	1.34	1.18	1.28	1.24	1.25	1.16	1.15	1.15	1.18	1.13	1.14	1.11
Exe	1.12	1.13	1.10	1.16	1.02	1.06	1.03	1.10	1.14	1.08	1.07	1.05	1.15	1.10	1.10
Region	1.13	1.15	1.09	1.19	1.07	1.16	1.11	1.15	1.11	1.09	1.09	1.08	1.08	1.11	1.11
Week no	25	30	22	27	30	33	29	27	24	27	29	32	24	24	29

TABLE 2.6 Likely Average Annual SWWSL Public Water Demand Forecasts, Assuming Leakage Targets are Met

Year	FORECAST DEMAND (Ml/d)						
	Colliford	N Devon	Plymouth	SW Devon	Allers & Pynes	E Devon	Total
1991	149	70	91	91	59	37	495
1996	140	64	94	84	59	35	475
2001	154	70	100	90	63	37	514
2006	169	77	106	97	68	40	555
2011	184	84	111	103	72	42	596
2016	200	91	118	109	77	45	640
2021	216	98	124	116	82	48	685

TABLE 2.7 Likely Peak 4-Week Public Water Demand Forecasts, Assuming Leakage Targets are Met

Year	FORECAST DEMAND (Ml/d)						
	Colliford	N Devon	Plymouth	SW Devon	Allers & Pynes	E Devon	Region
Peaking Factor (1989)	1.15	1.07	1.07	1.19	1.06	1.15	1.11
1991	171	75	97	108	62	42	550
1996	160	68	101	100	63	40	527
2001	177	75	107	107	67	43	571
2006	194	82	113	115	72	46	616
2011	211	90	119	123	76	49	662
2016	230	97	126	130	81	52	710
2021	248	105	133	139	86	56	760

TABLE 2.8 Population Forecasts From 'Review of Consumption Forecasts for Potable Water Supply, 1986-2011', Wessex Water Authority 1987

Water Supply	Resident Population (000's)		
Region Division	1991	2001	2011
Bristol Avon	306.5	320.5	333.6
Somerset	351.4	377.5	398.0

TABLE 2.9 Forecast Per Capita Consumption for Wessex Water Supply Divisions from "Review of Consumption Forecasts for Potable Water Supply, 1986-2011", Wessex Water Authority, 1986

Water Supply Division	Per Capita Consumption (l/c/d)		
	1991	1996	2011
Poole and Dorchester Lane, Avon & Somerset Division	164.25	178.25	189.25
Salisbury Zone, Avon & Somerset Division	154.30	168.30	179.30
Bristol Avon Division	155.69	169.69	180.69
Somerset Division	144.57	158.57	169.57
Bournemouth and District Water Company	163.27	177.27	188.27
Bristol Waterworks Company	164.45	178.45	189.45
West Hampshire Water Company	169.89	183.89	194.89

TABLE 2.10 Adjusted Component Demands for Somerset Division

		1991	2001	2011
1	<u>Unmetered Demand</u>			
	Population (000's)	351.4	397.5	398.0
	Connected population (000's)	328.4	354.5	375.0
	Per Capita Consumption (l/c/d)	153.19	169.34	180.42
	Demand (Ml/d)	59.8	70.8	79.3
	% of total	47	47	49
2	<u>Metered Demand</u>			
	Demand (Ml/d)	51.1	60.9	62.5
	% of total	40	40	38
3	<u>Unaccounted For Water</u>			
	Demand (Ml/d)	17.2	19.4	21.3
	% of total	13	13	13
4	<u>TOTAL DEMAND</u>	128	151	163

<u>Assumptions</u>

(a) % of total in each of three categories identified is as forecast by WWA (1987)

(b) Connected population is as forecast by WWA (1987)

(c) Total demand as forecast by WW (1990)

TABLE 2.11 Adjusted Component Demands for Avon Division

		1991	2001	2011
1	Unmetered Demand			
	Population (000's)	306.5	320.5	333.6
	Connected population (000's)	288.7	302.7	315.8
	Per Capita Consumption (l/c/d)	169.36	188.71	201.10
	Demand (Ml/d)	57.0	66.2	73.1
	% of total	50 328	52	54
2	Metered Demand			
	Demand (Ml/d)	36.2	40.6	43.9
	% of total	32	32	32
3	Unaccounted for Water			
	Demand (Ml/d)	20.8	20.2	18.9
	% of total	18	16	14
TOTAL DEMAND		114	127	136

TABLE 2.12 Extrapolated Average Annual Forecast Demand for Somerset and Avon

	Predicted total demand (Ml/d)			
District	1991	2001	2011	2021
Avon				
Low				136
Likely	114	127	136	146
High				156
Somerset				
Low				168
Likely	128	151	163	176
High				184

Assumptions

(1) Likely forecast achieved using 2001-2011 growth rate
(2) Low forecast achieved using curve fitting
(3) High forecast "mirror image" of low forecast
(4) Peaking factor of 1.15 to be applied to above figures in order to generate 4-week peak demands.

TABLE 2.13 Licensed Daily Private Abstractions Given By Purpose and Source Type (Ml/d)

Supply Zone	Spray Irrigation			Agriculture			Industrial Processing		
	GW	SW	Total	GW	SW	Total	GW	SW	Total
Colliford	8.6	15.0	23.6	6.1	0.2	6.3	85.1	22.9	108.1
*Roadford N.Devon & Plymouth	1.7	6.2	7.9	5.8	0.1	5.8	18.9	39.1	58.0
Roadford SW Devon	1.5	4.5	5.9	5.1	0.1	5.1	2.3	2.5	4.7
Allers & Pynes	12.0	22.7	34.7	9.4	0.1	9.5	4.6	16.0	20.6
East Devon	2.0	11.3	13.3	5.7	0.1	5.8	0.3	10.3	10.6
Total	25.8	59.7	85.4	32.1	0.6	32.5	111.2	90.8	202.0

* Includes the R Lynher catchment which is part of the Colliford zone.

GW = Groundwater SW = Surface Water

TABLE 2.14 Forecast of Daily Spray Irrigation Demand Ml/d (Assuming 100% Uptake of Authorised Quantity)

Supply Zone	Lower bound forecast +1% pa				Upper bound forecast 4% pa			
	1991	2001	2011	2021	1991	2001	2011	2021
E Devon	13.3	14.7	16.2	17.9	13.3	19.7	29.1	43.1
Allers & Pynes	34.7	38.3	42.3	46.8	34.7	51.4	76.0	112.5
Roadford SW Devon	5.9	6.5	7.2	8.0	5.9	8.7	12.9	19.1
Roadford N Devon & Plymouth	7.9	8.7	9.6	10.6	7.9	11.7	17.3	25.6
Colliford	23.6	26.0	28.8	31.8	23.6	34.9	51.7	76.5
Total	85.4	94.2	104.1	115.1	85.4	126.4	187.0	276.8

Daily licensed quantities extracted from a NRA Summary of licenses of November 1991.

TABLE 2.15 Forecasts of Daily Licensed Agricultural Demand Ml/d (Assuming 100% Uptake of Authorised Quantity)

Supply Zone	Lower bound forecast -1% pa				Upper bound forecast +1% pa			
	1991	2001	2011	2021	1991	2001	2011	2021
E Devon	5.8	5.2	4.7	4.2	5.8	6.3	7.0	7.7
Allers & Pynes	9.5	8.6	7.8	7.0	9.5	10.5	11.6	12.8
Roadford SW Devon	5.1	4.6	4.2	3.8	5.1	5.6	6.2	6.9
Roadford N Devon & Plymouth	5.8	5.2	4.7	4.3	5.8	6.4	7.1	7.8
Colliford	6.3	5.8	5.2	4.7	6.3	7.1	7.8	8.6
Total	32.5	29.4	26.6	24.0	32.5	35.9	39.7	43.8

Table 2.16 Forecasts of Daily Industrial Processing Demand Ml/d (Assuming 100% Uptake of Authorised Quantity)

Supply Zone	Lower bound forecast -1% pa				Upper bound forecast +1% pa			
	1991	2001	2011	2021	1991	2001	2011	2021
E Devon	10.6	9.6	8.7	7.8	10.6	11.7	12.9	14.3
Allers & Pynes	20.6	18.6	16.8	15.2	20.6	22.8	23.9	27.8
Roadford SW Devon	4.7	4.3	3.8	3.5	4.7	5.2	5.7	6.3
Roadford N Devon & Plymouth	58.0	52.5	47.4	42.9	58.0	64.1	70.8	78.2
Colliford	108.1	97.8	88.4	80.0	108.1	119.4	131.9	145.7
Total	202.0	182.8	165.1	149.4	202.0	223.2	245.2	272.3

Daily licensed quantities extracted from NRA summary of licences recorded in November 1991

3 PRESENT LEVEL OF RESOURCE DEVELOPMENT

3.1 Available Data

Information about public and private water supply sources exists in the following forms:

From the NRA:

- database of licence details (public and private supplies), from which were derived two summaries of public water supply (PWS) abstraction licences (dated 1.11.89 and 27.12.90) and a summary of private abstractions by river catchment (dated 28.11.91);

- archive of abstraction licences (files of information about each licence and, in some cases, information about yield estimates);

From SWWSL:

- regional and district water situation reports showing output from WTWs, average weekly demands, yearly demand averages;

- summary of annual licensed quantity and estimated peak period drought reliable yields of PWS abstractions by former supply districts (Fal, Fowey, etc) (11.1.91);

- summary of annual licensed quantity and 4-week peak period drought reliable yields of PWS abstraction in SWWSL strategic supply zones (Colliford, etc) (15.10.91).

From Wessex Water:

- available resource as deduced from the planning diagram in their demand forecast reports.

Further information about existing sources is to be found in applications made by SWWSL for drought orders.

The peak period drought reliable yield (DRY) in the SWWSL summaries is given as the source output that can be maintained during a severe dry year - typically 1975-76. That year is seen as the nearest modern equivalent to a 1 in 50 year drought event; analysis of gauged flows for the period April 1975 - September 1976 suggests return periods at individual sites ranging between 1 in 10 years and 1 in 95 years (19). Peak yields are provided in many cases for groups of sources, where these are operated in conjunction.

Using the SWWSL October 1991 summary, a best estimate of total peak period DRY of all licensed sources in each strategic zone has been prepared, by a summation of the SWWSL yields and infilling with the annual licensed amount where necessary (see Appendix D). The SWWSL estimate of DRY constitutes some 98% of this composite yield estimate. A resumé of the data is presented in Table 3.1.

Information on the operation of existing SWWSL and WW sources was obtained from interviews with NRA and water company staff, reviews of development reports (see reference list) and in-house knowledge.

3.2 Existing Public Water Supply Sources and Yields

3.2.1 General

As noted in Section 2.2, the region's resources have been divided into the five SWWSL strategic supply zones of Colliford, Roadford North Devon, Roadford South West Devon, Allers and Pynes and East Devon. The yields given in this section are those estimated to be sustainable during a 4-week peak demand period over a 1 in 50 year drought, often taken as 1975-76.

In some cases the 1975-76 equivalent DRY is based upon operational experience, whilst in others - notably the strategic reservoirs of Colliford, Roadford and Wimbleball - it is based on simulation modelling using a synthesised 1 in 50 year rainfall volume, distributed according to the 1975-76 rainfall pattern. There are also known to be some anomalies in the data. For example, the Roadford simulation is understood to allow for a 5% reduction in demand due to drought measures, while the Wimbleball simulation was based on annual average demands; peak period yields were deduced by factoring average annual ouputs by the appropriate peaking factor.

Despite these anomalies, it is understood that yields have generally been assessed by SWWSL on as consistent a basis as is possible.

3.2.2 Colliford

The locations of the Colliford supply zone sources are shown in Figure 7, and their collective DRY is given Table 3.1.

The principal element of water supply in the zone is Colliford/Siblyback reservoir system. Colliford Lake, sited on Bodmin Moor, is the second largest reservoir in the South West (after Roadford) and fulfils a key role in the current water resource strategy in the South-West. Operating in conjunction with direct river abstractions at Trekelvesteps and Restormel on the River Fowey, Colliford is estimated to provide 109 Ml/d over a 4 week peak period in a 2% drought.

The Siblyback reservoir is operated in conjunction with the abstraction on Withybrook and has a DRY of 39 Ml/d, of which 30 Ml/d is used to support river abstractions on the Fowey and 9 Ml/d on the Withybrook at Bastreet. Colliford and Siblyback regulation releases are abstracted from the Fowey and treated at Restormel WTW. The water is pumped to a high level balancing reservoir from which it gravitates through a trunk main to supply West Cornwall. Water is also pumped either direct to the DeLank WTW in the north or gravity fed to the St Cleer works in the east.

The total 4-week peak DRY of the Colliford/Siblyback system is 148 Ml/d, which represents 72% of the total developed pws resources of 204 Ml/d in the Colliford zone.

The second largest resource group in the Colliford supply zone is located in the West of Cornwall and comprises Drift, Stithians, Argal and College reservoirs. The combined DRY of these reservoirs is 40.9 Ml/d.

The remaining reliable resources in Colliford consist of a number of small groundwater abstractions in West Cornwall, including:

- the small Crowdy reservoir (6Ml/d), and
- an abstraction on the River Porth at Rialton (6Ml/d), supported by Porth Reservoir.

3.2.3 Roadford - North Devon & Plymouth

Licence and DRY estimate details for the public water supply sources located within the Roadford North Devon & Plymouth strategic supply zones are summarised in Table 3.1, and the locations of the sources are shown in Figures 8 and 9. The yield data presented are derived from the most recent information provided by SWWSL (October 1991) and in some cases (eg R Yeo, Loxhore and Bratton Stream) differ slightly from values provided in connection with the earlier work on the Roadford Study (20). It is assumed that the newer values reflect SWWSL's ongoing review of its source ouptuts.

The principal public source in the Torridge catchment is Meldon Reservoir, located in the headwaters of the River Okement, which acts as a direct supply source and also supports abstractions on the River Torridge at Torrington (see Figure 8). Meldon has a DRY of 21.2 Ml/d and supports a Torrington abstraction of 4.6 Ml/d (DRY). The abstraction on the River Taw at Newbridge can at present be supported by a transfer from the River Exe at Exebridge, but the relevant licence is due to expire in 1995. Thus no allowance has been made for the Exe-Taw transfer. The water from the Exe is all included in the estimated 75.2 Ml/d DRY for Wimbleball in the Allers & Pynes supply zone (Section 3.2.5).

Other sources in North Devon include Loxhore Pond on the River Barnstaple Yeo which, in conjunction with an abstraction from the neighbouring Bratton Stream, provides a DRY of 6.4Ml/d and Wistlandpound

Reservoir which is fed by abstractions on the River Bray at Brockenburrow and Leehamford (DRY of the three sources 11.1Ml/d). Taw Marsh, in the headwaters of the River Taw, is the only groundwater public water supply source in the zone. However, Taw Marsh has been associated with recent concerns over low river flows and has a drought reliable yield of zero.

The small Jennetts reservoir near Bideford is operated in conjunction with a river abstraction on the River Yeo and has a DRY of 2.2 Ml/d. There are also a number of small direct supply impounding reservoirs - Slade, Gammaton and Holywell - which together supply a DRY of 2.6 Ml/d. Without detailed data on the unsupported river abstraction on the West Ilkerton River, the DRY has been assumed to be 1.1 Ml/d, as licensed.

Future increase in demand in North Devon will be met by increased abstractions from the River Torridge and bulk supplies from Roadford via Northcombe WTW.

Prior to the construction of the Roadford Reservoir, the principal public water supply sources serving Plymouth were the River Tavy abstraction at Lopwell and the direct supply from Burrator Reservoir. Burrator is supported by an inter-catchment transfer from the Upper Dart tributaries via the Devonport Leat.

Water from both Lopwell and Burrator is transferred to Crownhill Water Treatment Works (WTW) for supply to Plymouth. The Devonport Leat/ Burrator system also supplies the Dousland WTW serving Yelverton (see Figure 9).

Roadford is the largest reservoir in the Region, and follows Wimbleball and Colliford as the third major lake to be built under SWWSL's strategy to meet the region's water demands into the 21st century.

Following completion of the Roadford scheme, the zone's supplies will be augmented by:

- a new abstraction on the River Tamar at Gunnislake, supported by regulating releases from Roadford. Water from Gunnislake is to be treated at a new WTW at Roborough, north of Plymouth;

- increased abstraction on the River Tavy at Lopwell with transfers from Gunnislake;

- direct abstractions from the reservoir, transferred to a new WTW at Northcombe near Roadford and hence to Torrington via the North Devon water main;

- increased abstraction from the River Torridge at Torrington.

In addition to the provision for bulk transfer of treated water from Roadford to Torrington, there is a facility to transfer water from Gunnislake and/or Burrator to Littlehempston WTW on the River Dart (Roadford South Devon

Strategic Zone). This is a raw water transfer at present, but will be commissioned as a treated water transfer when the new Roborough WTW is operational.

For the purposes of this study, the drought reliable yield for the Roadford system, including Burrator and Lopwell, has been taken to be 197 Ml/d. This figure reflects the conjunctive use opportunities with other sources as noted above. Although the operating rules for Roadford have yet to be finalised, the actual yield is not anticipated to be significantly different. The Roadford system represents 75% of the total 259.8Ml/d DRY resources of the Roadford North Devon and Plymouth strategic supply zones.

The remaining sources in these zones with significant DRY include the Upper Tamar Lake (8.2 Ml/d), and the River Erme (3 Ml/d). The River Erme abstractions are operated in conjunction with a storage lake.

3.2.4 Roadford - South West Devon

Licence and yield estimate details for public water supply sources located within Roadford South West Devon strategic zone are summarised in Table 3.1 and Appendix D, and the locations of the sources are shown on Figure 9.

Roadford South West Devon supply zone has a number of groundwater public water supply sources. However, with the exception of the radial collectors (rannies) and boreholes at Littlehempston on the River Dart, the DRY from these sources is small.

The direct river abstraction, rannies and boreholes at Littlehempston on the River Dart have a combined DRY of 24.9Ml/d, of which 15.9Ml/d is assumed to be supplied by the rannies and boreholes. However, it is known that the latter yield is obtained mostly at the expense of surface flows in the River Dart. The total yield represents 35% of the peak period DRY in the zone.

The other main drought reliable sources in South West Devon are Avon Reservoir, which is operated in conjunction with the Bala Brook abstraction, and Venford Reservoir, operated in conjunction with the Swincombe Intake. They supply 9.3Ml/d and 8.2Ml/d DRY respectively, representing 24% of the overall peak 4 week DRY of 71.75 Ml/d for the Roadford South West Devon supply zone.

In the upper Teign catchment Fernworthy Reservoir, operated in conjunction with Kennick, Tottiford and Trenchford Reservoirs, provides a direct supply DRY of 23.9 Ml/d.

Under the Roadford Scheme it is proposed that the direct river abstraction from the Dart will be increased in winter and treated at an extended WTW at Littlehempston. The recently commissioned South Devon link main allows raw water to be transferred from the new Tamar intake at Gunnislake associated with Roadford reservoir. Eventually, it will be possible to transfer treated water from the new Roborough WTW north of Plymouth via this link.

3.2.5 Allers & Pynes

The Allers & Pynes strategic zone includes the Exe catchment area within SWWSL boundaries, but excludes the Otter, Yarty & Axe catchments.

Licence and yield estimate details for the public water supply sources located within Allers & Pynes zone are summarised in Table 3.1 and Appendix D, and the locations of the sources are shown in Figure 10.

The principal public water supply sources are the River Exe abstractions at Bolham and Pynes (combined peak period DRY 75.2 Ml/d). These abstractions are supported by releases from Wimbleball Reservoir, sited on the Haddeo River in the upper Exe catchment. Wimbleball reservoir is owned and operated jointly by SWWSL and Wessex Water Plc, who take a direct supply from it via their Maundown Treatment Works, near Wiveliscombe.

The yield of 75.2 Ml/d available to SWWSL from the Wimbleball system represents 97% of the total DRY in the Allers & Pynes zone.

The remaining resources in the zone consist of a number of small groundwater abstractions such as Allers and Sheldon springs. Such sources have a combined DRY of 2.7 Ml/d.

3.2.6 East Devon

Licence and yield estimates for the public water supply sources located within East Devon strategic zone are summarised in Table 3.1 and Appendix D, and the locations of the sources are shown in Figure 10.

The zone includes the catchment areas of the River Otter, Yarty and Axe.

Of the five SWWSL strategic supply zones, East Devon has the highest dependence on groundwater, which accounts for about 30 Ml/d or just over 90% of the zone's total DRY of 31.9 Ml/d.

The main groundwater sources are in the Trias aquifer in the lower Otter valley. The two principal groupings are the Greatwell boreholes (8.5 Ml/d) and the Colaton Raleigh, Dotton and Otterton Boreholes (12.6 Ml/d). The remaining groundwater sources are operated independently and are located in the upper catchments of the Rivers Otter and Yarty, and in the lower Axe valley.

The only surface water abstractions in the zone include the Squabmoor Reservoir (0.9 Ml/d DRY) operated in conjunction with the Yettington Intakes, Holyfords ponds (0.9 Ml/d DRY) near Seaton, and the unsupported River Axe abstraction at Whitford Bridge (0 Ml/d). A licence is also held to take water from the Budleigh Brook, although it has not yet been utilised by SWWSL.

3.2.7 Wessex Water

For resource planning purposes, Wessex Water sub-divide their area into four districts:

- Somerset;
- Avon;
- Salisbury;
- Dorset.

This report is concerned primarily with the Somerset area, most of which can be supplied from Wimbleball reservoir. However, because of the facility to transfer available resources between Avon and Somerset, the two sub-areas are considered together.

Existing resources in Somerset comprise some 170Ml/d, including a transfer from Avon which is at present about 14Ml/d. These yields are sustainable in a peak period during a 2% drought. Of the 170Ml/d yield in Somerset, about 100Ml/d is surface derived, mainly from reservoirs of which Wimbleball, Clatworthy, Sutton Bingham and Durleigh are the most significant. These four together account for about 80Ml/d of the drought reliable resources available to Somerset. Wimbleball reservoir is operated and owned jointly by Wessex Water and SWWSL. Wessex at present abstract an average of 28Ml/d directly from the reservoir but have an average annual entitlement of 31.8Ml/d (daily peak 45Ml/d). As noted above, the SWWSL yield from the reservoir is derived via river regulation.

The remaining three reservoirs operate in direct supply, and, with the exception of Durleigh, all are impounding; inflow to Durleigh is augmented by pumping from the Bridgwater canal, which in turn is fed by diversion from the River Tone at Taunton.

The remaining 70Ml/d of yield available to Somerset is drawn from a variety of groundwater sources, including a 14Ml/d transfer from Avon district.

Current peak period Avon resources amount to about 142Ml/d, and are principally groundwater derived.

Planned developments in Somerset and Avon will increase available resources by 31Ml/d.

3.3 Overview of Present Public Water Supply System

3.3.1 General

In common with water supply systems elsewhere, that in the South West has grown through progressive integration of relatively small schemes originally intended to meet localised supply needs. The underlying philosophy was that water is a cheap commodity which is expensive to move. Whilst integration has progressed as demand for water has increased, the process is not complete. Major pipelines linking the Roadford system with North and South West Devon have only recently been commissioned; there are two links between the Exe system and East Devon - the coast main and the Allers Honiton pipeline - but the capacity of both is understood to be limited. There are no significant links between the Wimbleball and Roadford or Roadford and Colliford strategic zones. A small raw water pipeline linking the Upper Exe with North Devon is reliant upon an abstraction license which is due to expire in 1995.

Most of the major demand centres in the South West are located on estuaries or sea coasts; sewage disposal is thus largely to tidal waters, so there is limited effluent re-use.

The hydrology of the South West is such that summer flows are often very low; capture and storage of surplus winter rainfall by means of reservoirs and making good use of East Devon's aquifer storage are thus essential if reasonable demands for water are to be met at an acceptable price in terms of environmental impact.

3.3.2 Surface Water Sources

Surface derived public water supplies in the South West are based upon:

- reservoirs for direct supply;
- reservoirs for river regulation, and the direct river abstractions which they support;
- unsupported river abstractions.

Direct supply reservoirs are drawn upon for public water needs throughout the year, whereas releases from regulating reservoirs (over and above the compensation flow) are only necessary at certain times of year, when the natural flow in the river at a certain point falls below a threshold value (prescribed flow). The direct river abstraction downstream can thus operate throughout the year, using natural flows when they are above the threshold, and flows augmented by reservoir releases at other times.

Unsupported river abstractions are usually subject to a flow threshold beneath which they cannot be operated, although this is not always the case. Thus it is likely that many such sources cannot be relied upon during extended dry periods, when demand is likely to be at its highest, and other available resources at their most scarce. This is overcome in some cases by operating such sources conjunctively with direct supply reservoirs or groundwater sources. The unsupported river abstraction is used in winter, and the reservoir in summer. Thus the yield of the two sources can be enhanced above the sum of their individual drought reliable yields.

Early water supply schemes were developed by local councils to meet the needs of a particular town and its immediate surroundings; they tended to be based upon unsupported river abstractions or, if summer flows were insufficient, small local direct supply reservoirs.

As the system has become more integrated, the tendency has been towards larger reservoirs of strategic importance to a significant proportion of the region. These have at least part of their yield dedicated to regulation to support downstream river abstractions; such a system is particularly suited to the South West, where there is no shortage of water in winter but summer base flows are lower than is typically the case for comparable catchment areas elsewhere in England and Wales. River regulation reservoirs have a higher specific yield than those used for direct supply, and allow intakes to be sited at or near the tidal limit, where available flows for abstraction are highest and the related environmental impact is likely to be least.

In Table 3.2, reservoir net storages and drought reliable yields are compared with the annual average run-off and total public water supply DRY for a selection of local rivers. It is seen from the table that the degree to which run-off is harnessed by reservoirs varies enormously across the region. Using the storage/run-off ratio as a guide, the Fowey is by far the most developed river, whilst the Torridge, Dart and Teign are relatively lightly used. The Tamar and Exe are exploited to a greater degree than the Torridge, Dart and Teign, but to a significantly lesser extent than the Fowey.

A further measure of storage value is presented in Table 3.3, in which net storage is compared with average daily water demand. Various points arise from the Table:

- overall, current storage could meet demand for 7½ months at the average annual rate in the SW Region, assuming reservoirs were full at the outset and thoroughly integrated. This sustainable period drops to 7.1 months if it is assumed that demand over the period is 5% above annual average;

- in sub-regional terms, Colliford strategic zone has the longest sustainable period, of 9 months, and Roadford zone, the shortest (6.5 months);

- prior to commissioning of Roadford, the sustainable period for that zone would have been about 2 months.

Bearing in mind the very recent introduction of Roadford, and the fact that its yield will not be fully committed until well into the next century, it is concluded that the present level of storage in the SWWSL supply area is more than adequate by this measure. An overall provision of 4-5 months is probably sufficient.

3.3.3 Groundwater Sources

Groundwater sources include schemes based upon:

- conventional aquifers
- alluvial gravels
- shafts and adits

The main conventional aquifer in the region comprises Triassic pebble beds and sandstone underlying parts of South East Devon around the Otter valley. This has been relatively well developed, with an aggregate annual authorised quantity for public supply equivalent to some 43Ml/d. However, there have been operational and water quality problems associated with the sources, so that the current peak period DRY is only about 25Ml/d. Plans to develop the wellfields to restore the DRY are being drawn up.

Alluvial gravels schemes range from headwater schemes such as Taw Marsh, to down-catchment systems such as that centred on Littlehempston treatment works near Totnes. The former has a negligible drought reliable yield, and use during times of low flow is due to be discontinued due to adverse impacts on fisheries and angling. The latter affords an estimated DRY of about 16Ml/d, but is believed to deplete surface flows. The problems experienced in the Lower Dart with algal blooms during the recent drought may well have arisen partly because of reduced flows caused by the Littlehempston "groundwater" abstraction system.

The third type abounds in Cornwall. However, there are quality problems associated with many of the sources, and the yield of individual schemes is very low.

Total drought reliable groundwater yield for public supply in the region is estimated at about 52Ml/d, or 8% of overall developed resources. This is among the lowest of any of the NRA regions' dependencies on groundwater.

3.4 Private Abstractions

Private abstractions in the South West are nearly all unsupported river or groundwater based. Of the daily aggregate authorised quantity of 534Ml/d (excluding pisciculture and hydropower generation), 68% relates to surface sources, and 32% to groundwater (see Table 2.13).

Private surface abstractions for hydropower generation or pisciculture (not included in the above figures) have a low associated net use, but entail local diversion of a significant proportion of river flow and can thus be environmentally damaging. One hydropower scheme, on the River Tavy at Tavy Cleave, has a limited amount of associated storage which permits river regulation on a diurnal basis.

3.5 Environmental and Water Quality Considerations

The growing awareness of the environmental impact of existing water resource management, and the rapidly developing perception that many such impacts are unacceptable, mean that the yield of existing sources cannot be considered immutable. Some of the impacts, involving drying-out of reaches of streams or rivers, are blatant, but others are much more subtle and their significance is only now becoming apparent. A study of artificially induced low flow problems in the South West (6) identified some 109 sites throughout the Region where some adverse impact was perceived by one or more of the groups consulted. Most of these are attributed to direct surface water abstractions, reflecting the limited groundwater resources of the region. Some 72 are local abstractions for pisciculture, hydro-electric power generation or other industrial uses. Of the remaining 37, 24 are abstractions for public water supply. In a number of cases, the compensation flow below reservoirs was considered to be inadequate.

A review of abstraction licences suggested that problems may also occur at other sites. Priority action to remove the cause or mitigate the adverse impacts was recommended for 19 of the 109 sites.

The NRA is developing guidelines for the management of surface-water abstractions which take account of environmental concerns. However, many existing abstractions fall well short of the levels of environmental protection which are considered acceptable for new schemes. For example, many (mainly private) surface abstractions operate without a prescribed flow rule, even to the extent of complete drying-out of stretches of river. The NRA has recently been put in the difficult position of having to issue licences of entitlement for abstractions which they know are causing significant environmental damage.

In the past, efforts to limit the environmental impact of surface water abstractions have concentrated, understandably, on protection of low flows. However, there is now a growing understanding of the subtle relationship between variations in medium low flows and stream ecology. For example, migratory fish utilize minor spates and elevated flows for upstream migration, and periodic wetting of river margins can be most important in ecological terms. Most water undertakers take a responsible attitude to incorporating environmental safeguards into schemes where possible; however many sources, particularly those allowing considerable abstraction in dry weather, are too valuable to relinquish voluntarily without compensation or allocation of other resources. Nevertheless, the widespread and growing view that the environmental harm being done by many abstractions is unacceptable means that revocation or modification of many licences is likely, using an appropriate mechanism.

Some of the more noteworthy cases of adverse environmental impact are being caused by private abstractions operating by Licence of Right (Water Resources Act 1963). Loss of drought-reliable yield by revocation or modification of such licences would have to be made good with an alternative source, or be absorbed into a more efficient integration of sources.

It is not possible to make a reliable assessment of the likely impact of environmental concerns on yield of existing sources. The levels of acceptability of various degrees of the environmental impact is changing, as is our understanding of some of the more subtle impacts of abstraction. This clearly has an influence on the potential loss of yield from individual sources.

However, the rapidly changing perception of permissible levels of environmental impact in relation to water resources means that some estimate of the likely associated derogation of reliable yield is essential for planning purposes (see Section 3.6 below).

Raw water quality of the majority of the public water supply abstractions is generally perfectly adequate for the purpose after appropriate treatment. Whilst nitrate levels in rivers do achieve significant seasonal maxima, blending and/or significant treatment for their reduction in abstracted water is not yet necessary anywhere in the region. Similarly, problems associated with periodic algae blooms in direct supply reservoirs are being successfully overcome by a combination of reservoir management practices (eg destratification) and treatment.

In the 1990 Report on River Water Quality in England and Wales (7), 82% of the main river lengths in the South West are classified as suitable for public water supply. The most notable changes since the 1985 report, where 94% of river length was reported suitable, are the deterioration of the R Tamar and upper reaches of many of the region's smaller rivers. The prolonged periods of low flow during the two successive drought years (1988-1989) have had an adverse effect on river quality. Of the remaining 18% of rivers classified as poor or bad, a large proportion lie in West Cornwall, the Fal being the most significant. Quality problems here relate mainly to the China Clay Industry. Whilst this will remain active in the area in the medium term, it is possible to reduce the associated water quality problems.

Groundwater quality is also adequate, although close monitoring of nitrate and iron/manganese levels, coupled with occasional blending is necessary.

In summary, therefore, water quality is not a limiting issue from the viewpoint of further resource development.

3.6 Low Flow Debit

The Low Flow Study of the South West Region (6) identified some 109 sites where water abstraction was perceived to be causing environmental detriment. At all but 19 of these, the extent of the problem was not quantified. These 19 "worst sites" included flow depletions arising from abstraction for public water supply, hydropower generation and fish farming. The latter two categories are low net users of water and, while their abstraction can be very damaging locally, most of the water taken out is returned to the river a short distance downstream.

Further problems are associated with reservoirs which provide insufficient compensation flow to the river system downstream.

In order to evaluate the extent to which existing available resources may have to be cut back at some future date to limit adverse environmental impact, it has been assumed that:

- all reservoirs should have a compensation release of Q_{95} (i.e. the flow equivalent at the dam which would have been exceeded 95% of the time on average, under natural conditions prior to the impoundment), and that, where this is not the case, the yields should be adjusted by the amount by which Q_{95} exceeds the compensation flow;

- the low flow debit attaching to all other problem sites may be deduced from consideration of the public supply sources which feature in the top 19 low flow sites.

The "low flow debit" deduced in this way is equivalent to a drought reliable yield of 36Ml/d, as shown in Table 3.4. This amounts to some 6% of existing available resources for pupblic water supply. In preparing the Table 3.4, those reservoirs where compensation flow is measured a significant distance downstream from the dam have been excluded.

In the absence of more definite information on the scale of the Somerset/Avon low flow problem, it is suggested that the yield in that area should be adjusted by a similar proportion. Thus the peak period output of 343Ml/d when planned developments are in place would reduce by 21 to 322Ml/d. It is acknowledged that Wessex have a higher dependence on groundwater (with which low flow problems are more commonly associated) than SWWSL; however most of the SWWSL debit arises through adjustments to reservoir compensation flow, and hence storage output. This is seen as analogous to reducing groundwater source output in order to enhance summer base flow and spring discharges.

3.7 Shortcomings of Present System

Water has traditionally been viewed as a cheap commodity which is costly to move. This has in the past governed the manner in which resources have been developed for public supplies. Typically:

- sources closest to the centres of demand have been developed first;

- wherever possible, gravity has been used to help move water to the customer premises, and remove used water from them

- too little attention has been paid to proper accounting of abstracted water, and reduction of waste.

The past tendency to develop localised sources means that there are a large number of schemes with small yields in the South West. These are costly to link up into an integrated system.

The desire to make use of gravity has led to abstractions in the upper reaches of rivers, and discharges of used effluents well downstream or into tidal waters. Because most of the larger towns in the South West are around the coast, effluent discharge to tidal waters is very common in the region. Thus the opportunity to augment river flow with suitably treated effluent is often missed, and, with it, the option to make better use of available resources through further abstractions lower down the catchment which would benefit from such augmentation. Obviously flows will be lower in upper catchments than towards the tidal limit, so sources developed there will have relatively lower yields; furthermore, the effect of abstractions in upper catchments is more noticeable in environmental terms.

Poor accounting for water, and past indifference to waste, is a major focus for criticism of the industry by both those concerned at perceived environmental damage caused by existing abstractions, and those opposing new resource developments. The national average of 26% of treated water put into supply that is unaccounted for represents a level of loss which would be unacceptable with any commodity of higher value; it is rapidly coming to be seen as undesirable in the case of water, where the environmental implications of over-abstraction are ever more widely recognised. This figure excludes losses of raw water between abstraction site and treatment works.

In the South West, unaccounted for water was estimated at 29% of the quantity put into supply in 1990 (1).

A related issue is the long-held contention that consumer demand should be met in full, if necessary by the development of further resources. The perception that consumers should be encouraged to moderate their demands - at least by reducing wastage in the home, if not by attempting to use less water for domestic needs - is relatively new, although demand management at times of drought is an established procedure within the industry.

As noted in Section 3.4, a large number of high rate, non-consumptive agricultural and domestic abstractions exist in the region, particularly for pisciculture and power generation. Most were established prior to the imposition of normal licensing controls of these uses under the 1989 Water Act. Many are not subject to prescribed flow conditions, and take a very high proportion of the natural flow during low flow periods. Because these abstraction rights are protected, just like those of other abstractors, they impose severe restrictions on the NRA's ability to allow further consumptive abstractions upstream in many cases. This provides a further justification for promoting consideration of tidal limit, rather than up-catchment direct river abstractions for future schemes.

In summary, therefore, the shortcomings of the existing system are:

- poor "housekeeping" by suppliers and consumers alike, whereby levels of wastage and unaccounted for water are too high;

- little provision for resource conservation through means such as effluent re-use;

- dependency on some sources which are inappropriately placed within river catchments in relation to achievable yield and/or environmental detriment.

Although considerable progress has been made in the South West in recent years with strategic integration of sources, there remains scope for further improvement.

Any sensible strategy for resource development must take these shortcomings into consideration before addressing options for new schemes. In particular, scope for the following needs to be addressed:

- reducing the rate of demand growth through improved "housekeeping", reduced wastage and more efficient water use by consumers;

- modifying the way in which some sources are operated, to reduce their environmental impact and/or increase their yield (for example, by converting upper catchment direct supply reservoirs to river regulation);

- greater re-use of treated effluent.

Measures taken to limit demand during droughts are also relevant. The companies have standards of service relating to water supply, pressure and frequency of hosepipe bans. It is reasonable to consider the extent to which demand management should be undertaken during droughts in order to minimise environmental impacts of high rates of abstraction at such times.

TABLE 3.1 Summary of SWWSL Supply Area 4-Week Peak Drought Reliable Yields (Ml/d)

Zone	Surface Water	Groundwater	Total (rounded)
Colliford	203.6	0	204
Roadford N Devon & Plymouth	259.7	0.1	260
SW Devon	54.5	17.25	72
Allers & Pynes	75.2	2.7	78
East Devon	1.8	30.1	32
Total (rounded)	595	50	646

TABLE 3.2 Resource Use and Reservoir Storage in South West Region

River System	Fowey	Tamar	Torridge	Dart	Teign	Exe
Main river gauging station	Restormel	Gunnislake	Torrington	Austin's Bridge	Preston	Thorverton
Annual Average Runoff (AAR) (Ml/d)	432	1959	1327	953	808	1369
Public Supply Yield (PSY) (Ml/d)	139	c100*1	31	34	24	121*2
Reservoirs	Colliford Siblyback	U Tamar Lakes Roadford	Meldon Melbury	Venford	Fernworthy Kennick, etc	Wimbleball
Net Storage (Ml)	31722	35835	3238	773	3491	21320
Reservoir Yield (Ml/d)	139	100*1	25	8	24	121*2
Total Public Yield/AAR	0.32	0.05	0.02	0.04	0.03	0.09
Storage/AAR (days)	73	18	2.4	0.8	4.3	16
Reservoir Yield/ AAR	0.32	0.05	0.02	0.01	0.03	0.09

*1 Yield of reservoir itself difficult to disaggregate from that in conjunction with related sources.

*2 Including WW entitlement.

TABLE 3.3 Reservoir Net Storage vs. Demand

Strategic Zone	Net Storage (Ml)	Av. daily demand AAD (Ml/d) (1991)	No. of days AAD which could be met from full reservoirs	
Colliford	41,400	149	278	
Roadford/N Devon & Plymouth	45,053	161	280)	201
Roadford/S W Devon			61)	
Allers & Pynes	21,320	57	374)	227
E Devon	64	37	2)	
South West Region	113,391	495	229	

TABLE 3.4 Assessment of Yield Reduction Attributable to Low Flow Problems

1. Reservoir Compensation Flows

Reservoir	Compensation Flow (CF) (Ml/d)	Q_{95} Ml/d[1]	Yield Adjustment (= CF-Q_{95}) (Ml/d)
Drift	1.38	6.57	-5.19
Stithians	2.76	2.85	-0.09
Colliford	5.70	9.25	-3.55
Siblyback	3.11	4.32	-1.21
U. Tamar Lake	2.76	1.56	+1.20
Roadford	8.99	2.94	+6.05
Burrator	2.59	8.99	-6.40
Meldon	3.89	13.05	-4.58[2]
Fernworthy	5.70	6.65	-0.95
Venford	1.81	2.25	-0.44
Avon	5.88	10.80	-4.92
Wimbleball	3.0	6.91	0[3]
Subtotal Yield Adjustment Related to Low CF:			say -20Ml/d

1 Q_{95} values derived from Institute of Hydrology data supplied by NRA.

2 50% of CF-Q_{95}, as gauging station is 0.75km downstream of dam site.

3 The figures given for Wimbleball are misleading, since the compensation flow from the dam is supplemented by leakage flows of approximately 6.0 Ml/d from the Reservoir.

TABLE 3.4 (continued) Assessment of Yield Reduction Attributable to Low Flow Problems

2. Public Water Supply Abstractions Among Principal 19 Low Flow Sites

Site	Yield Reduction (= low flow adjustment) Ml/d
Devonport Leat (U. Dart)	10
Leehamford (R Bray)	3
Yealm headwaters	3
Subtotal Yield Adjustment for Worst Low Flow Sites:	16
Total Yield Adjustment for Low CF and worst low flow sites:	36

4 OPTIONS FOR RESPONDING TO DEMAND GROWTH

4.1 The Need for More Water

In Section 2, demand forecasts are presented which show that:

- peak 4-week public water demand in the SWWSL supply area is forecast to grow from 550Ml/d in 1991 to a likely level of about 760Ml/d by 2021, assuming a peaking factor of 1.11 for the region overall;

- corresponding figures for the Avon and Somerset portions of the supply area are 278Ml/d (1991) and about 370Ml/d (2021), assuming a peaking factor of 1.15;

- forecasting growth in consumptive private abstraction is very uncertain. Authorised abstractions could increase from the present 320Ml/d to as much as 593Ml/d, or decrease to 288Ml/d. The median value of 440Ml/d represents an increase of 120Ml/d. (These figures exclude pisciculture and hydro power generation).

The public water demand forecasts assume that current published targets for leakage control will be met, although in the case of SWWSL the dates by which they are to be achieved are seen as optimistic.

In Section 3, available peak period public water resources available in a 1 in 50 year drought (taken to be similar to 1976) are discussed. These are:

- 646 Ml/d in the SWWSL supply area;

- 312 Ml/d at present in the Avon and Somerset portions of the Wessex supply area, rising to 343Ml/d when programmed developments are in place (these developments exclude any additional water for Wessex from Wimbleball reservoir beyond the 31.8 Ml/d average current entitlement).

The "Low Flows Debit" discussed in Section 3.6 has not been deducted from the available resource figures quoted above. Taking these demand and available developed resources figures together, it is apparent that public supply shortfalls could occur during peak periods (unless preventative measures are taken) as follows:

- In the SWWSL supply area, commencing in about 2009 and growing to 114 Ml/d by 2021;

- In the Avon/Somerset part of the WW supply area, commencing in about 2012 and growing to 27Ml/d by 2021.

These dates and figures exclude any allowance for a margin of safety against unforseen or unquantified future changes such as global warming, and assume that:

- published leakage targets are achieved in full;

- no cutbacks are made in available resources due to environmental constraints;

- existing sources are fully integrated.

If a 5% planning margin on demand is allowed,

- the SWWSL deficit commences in 2006 and reaches 152Ml/d by 2021;

- the WW deficit commences in 2006 and reaches 46Ml/d by 2021.

Sub-regional deficits (excluding a planning margin) for the SWWSL supply area are shown on Figure 11.

The foregoing deficits are based on 'likely' forecasts. The 2021 deficits for 'high' and 'low' demand forecasts, excluding the 5% planning margin, are:

	'Low' Forecast Deficit	'High' Forecast Deficit
SWWSL	59	155
Avon & Somerset	7	48

The 'high' deficits are thus comparable to those deduced from the likely forecasts with 5% planning margin.

The estimates show that alternative measures to prevent the occurrence of deficits should be considered. Such measures would include one or a combination of the following three basic possibilities:

- water conservation measures and demand management;

- further development to augment existing sources;

- development of new sources.

The national water resources strategy study (1) has shown that utilisation of effective rainfall is relatively low in the South West compared with other regions. Transfers of additional resources into the SWWSL supply are thus seen as inappropriate while the possibility of further development of local sources remains. However, the national study also showed that further inter-regional transfer might be appropriate for the WW supply area, probably from Wales via the River Severn system.

Conservation measures and demand management involve the deliberate application of policies to reduce wastage and to influence the extent of public sector water demand, in order to make best use of existing available sources. The second two possibilities permit continuing unrestricted demand growth, and acceptance of the need to develop water resources further in order to meet it. Such a demand-led strategy has environmental implications which need to be considered carefully, so that the right balance is struck between demand management and further source development.

The scope for each of the above three basic possibilities in the South West is discussed in the remaining sections of Chapter 4, whilst specific strategy alternatives for each supply zone are identified and considered in Chapter 5.

4.2 Environmental and Licensing Considerations

4.2.1 Environment

General

Greatly increased awareness and understanding of the environmental impact of surface and groundwater abstraction means that new source developments for public water supply are likely to be conditional upon appropriate operating rules to ensure that they remain "environmentally acceptable" for the foreseeable future. However, the opportunity will be taken in the future to negotiate revised operating rules (and thus reduced yields) at existing sources when licence applications for new resource developments are under discussion. This has already occurred in connection with the Roadford scheme.

Further, recent experience has shown that the potential yield of proposed schemes may be highly sensitive to the operating rules that are applied. Thus proposed operating rules are likely to be a highly contentious issue during scheme promotion, particularly where environmental concerns make desirable more stringent rules than might have been applied to similar schemes in the past. This is likely to have fundamental repercussions on the choice of appropriate future developments, and upon the cost of securing future water supplied. It also means that the economic viability of approaches to reducing demand, eg leakage control and metering, may be transformed.

Clearly, any effective control of demand or demand growth could be used to reduce the environmental impact of existing abstractions; equally it could be used to delay the need for new sources, with no additional environmental impact or gain. Demand control does present the scope for reduction of impact if the overall policy embraces it.

The potential reduction in environmental impact by control of demand during periods of drought is considerable. It is suggested that this is a benefit that is not so far costed in the calculations of the economic viability of metering.

Surface Water

The most obvious environmental requirement in developing new resources is the protection of flows, in order to safeguard downstream biota and water quality, maintain wetland habitats and protect brackish water habitats in the estuary. Generally the most valid approach is that of a prescribed flow, below which abstraction must not take place. Usually the prescribed flow will be higher than minimum natural flows; guidelines developed by NRA South West are based upon natural Q_{95} plus a range of environmental weighting factors according to local conditions.

While protection of low flows is clearly important in ecological terms, it is likely that it has dominated consideration of environmental impacts to the neglect of some other aspects. Flow and level variations can be important in the maintenance of certain marginal habitats, and for the stimulation of movements of migratory fish. Rules limiting takes to 50% of the flow above a pmf, and temporary cessation of abstraction during minor spates, are concepts currently being examined to try and maintain some environmental variation and minimise detrimental impacts on the hydrological character of catchments.

Head of tide abstractions clearly offer considerable attraction in that any impact is limited to the tidal reaches of estuary. In many situations this can effectively reduce the impact to zero, as long as estuarine water quality can be protected. The needs of migratory fish entering the river may need careful protection in this situation, but there is likely to be scope for modulation of abstraction (eg 12 hours on, 12 hours off) to reduce impact. Further, it may be that a "window" of higher flows, when migratory activity is greatest, justifies protection to an even greater extent than very low flows. Modulated head of tide abstractions could thus be very valuable in providing water at very low flows as part of an integrated resource scheme.

In considering such abstractions, however, the implications for further private or public supply water resource developments upstream need to be considered. Because of the protected rights inherent in an abstraction licence, one can only be issued in respect of a head-of-tide site if there is sufficient available flow there over and above the net quantity (abstractions less returns) authorised upstream. Once the licence is granted, the scope to issue further licences for consumptive uses in the catchment upstream is constrained by the need to protect the abstraction quantity authorised at the head of tide. However, the scope to issue additional icences for non-consumptive abstractions in the catchment upstream would not be curtailed by a head-of-tide abstraction.

The greatest scope for further development of surface water resources, however, lies with increased use of higher winter flows, which involves storage.

This represents a most attractive option in environmental terms, as it allows a whole range of measures to protect low river flows or other aspects of hydrology that are considered sensitive. River regulation, carefully controlled by appropriate operating rules, can represent a positive environmental enhancement - especially at times of very low natural flow. The streams below reservoirs, if properly managed, can become fascinating and productive habitats in their own right. In most situations, reservoirs represent a considerable bonus in terms of wetland habitat, habitat diversity, fishing and other recreation activities. Although there are often strong objections in reservoir developments from a vociferous few who perceive personal disadvantage, once established they are highly popular and greatly cherished locally. They afford excellent dinghy sailing, trout fishing, and other forms of recreation.

Pumped storage to increase the reliable yield of reservoirs is also considered as an environmentally desirable development. Abstraction of winter flows is of minimal impact compared to the derived benefit of low flows being alleviated by adequate storage. Construction of pipelines from intakes to reservoirs can have an environmental impact, but careful routing and modern techniques of habitat restoration reduce this to a minimum.

Re-use of effluents generally represents a positive environmental benefit. It reduces the need for new resources, and the discharge of potentially polluting discharges. One of the most appealing developments is that of root-zone STW, producing very high quality effluents which can be discharged to small streams without significant impact. As an alternative to exporting the sewage downstream to large works, it means that more water is available to support the sensitive upper reaches of rivers. However, as most significant water use in the South West occurs along the coast, there is likely to be only limited scope for such measures

<u>Desalination</u>

There are significant environmental disadvantages associated with desalination. Water is produced by the direct or indirect burning of fossil fuels, thus contributing to possible climatic change problems. The brine waste has a salinity of between 50 to 70 parts per thousand. Increased salinity and higher pH, due to high carbonate/bicarbonate concentrations in the brine cause internal plant corrosion and may lead to high metal (Aluminium, copper, zinc, iron) concentrations. Brine from distillation plant in addition will be about 15°C above the ambient sea-water temperature.

These factors can reduce the ability of organisms to survive and/or grow or reproduce in localised brine disposal areas. The impact of brine varies from species to species, but is likely to cause most serious problems to benthic organisms. Being denser than normal sea-waters, the brine has a tendency to sink to the bottom, forming a blanket which sessile or slow moving organisms are unable to escape.

In planning a desalination plant, early consultation with the fishing industry is required to identify a brine discharge point with minimal environmental impact. If the brine is released into an estuary, shell fisheries may be damaged; in addition high salinity and metal concentration could form a barrier to migrating fish.

Groundwater

Little net increase in groundwater derived supplies can be foreseen in the South West, due to:

- very limited potential for further aquifer development;
- an increased public awareness of the potential problems of over-abstraction and low river flows;
- increasing understanding of some of the more subtle impact;
- lowering thresholds of public acceptance of environmental changes;
- the likely requirement to reduce the impact of many existing groundwater sources,

Although fraught with practical difficulties, artificial recharge of aquifers has considerable theoretical appeal, as there are likely to be general environmental benefits occurring from raised groundwater levels.

For a recharge scheme to be effective, certain hydrogeological conditions are required. In particular, the aquifer to be recharged needs to:

(a) have a utilisable storage deficit;

(b) be hydraulically distinct from the river system;

(c) possess groundwater flow characteristics which retain a significant proportion of winter recharge sufficiently long to allow summer abstraction, rather than losing it to riverflow earlier in the year.

There must also be a suitable source of water of appropriate quality to be used for recharge when needed.

The storage deficit could be developed by pumping during the summer. However, conditions (b) and (c) are not met in the principal groundwater area used for public supply in the South West.

A possible further constraint to such schemes is groundwater quality protection; a national groundwater protection policy is currently in preparation, and proposals for artificial recharge will be subject to review under the policy.

The conjunctive use of groundwater sources, especially to regulate stream flow for abstraction downstream, represents a more environmentally positive use of the resource than does direct abstraction. The Candover Scheme in Hampshire is of this type; abstraction near the tidal limit means that a considerable length of river benefits. Such schemes are not totally without adverse impact, however, as flows are reduced during the period of natural recharge. In the South West, conjunctive use opportunities are limited to those catchments in East Devon which are associated with a suitable aquifer, such as the Otter Valley.

4.2.2 Licensing Considerations

All significant public and private ground and surface water abstractions are now governed by licenses, for which application is made to, and determined by, the NRA (except that the NRA itself, if seeking a licence for river support pumping, for example, must apply to DoE). The purpose of these licenses is to:

- ensure available water resources are equitably allocated;
- guard against over-exploitation of water resources, and associated environmental damage.

When the abstraction licensing legislation was introduced in the early 1960's, emphasis tended to be placed on the first objective. This meant that licences stipulated only a maximum volumetric entitlement over a given period. Later licences specified such entitlement more closely - in terms of maximum daily, annual and occasionally monthly take, and restrictions as to when such amounts could be abstracted - usually related to prevailing flow conditions, although the method of measurement was not always specified. In recent years, licensing practice has focused increasingly on how an abstraction is operated, as well as the basic requirement for water. Such development is to be welcomed, since the impact of any abstraction with a given permissible daily take can vary enormously according to how it is used.

Determination of licence applications, therefore, is the tool which enables the NRA to ensure that demands are addressed in a consistent manner, and water resources are developed in a coherent manner. From the licence holder's viewpoint, a licence is an asset which entitles him to water under certain conditions, such conditions being modifiable only:

- with his consent;
- by formal application by the NRA.

In the latter case, the licence holder has a right of appeal and, possibly compensation.

It is important that the opportunities which the licensing legislation affords, both to maximise resource availability and to minimise environmental damage, are fully realised. This may be done through:

- ensuring that the existing legitimate interests and protected rights of other users of the aquifer or water course will not be derogated;

- specifying the maximum instantaneous, hourly, daily, monthly and/or annual permitted abstraction volumes appropriate to the circumstances;

- specifying appropriate minimum flow conditions below which abstraction must not take place, and an effective means of monitoring and policing these (eg by correlation with a telemetered gauging station nearby);

- if appropriate, specifying times (eg summer) when abstraction must not take place (this may impose a storage need on the licence applicant, for example if he wants to use water from a heavily committed stream for irrigation);

- encouraging location of points of abstraction away from sensitive headwater areas and/or where low flow problems exist towards areas where baseflow is higher and preferably supported by effluent returns or river regulation;

- where appropriate, agreeing detailed operating rules and/or specifying licence conditions which enable yield to be maximised whilst safeguarding environmental interests (for example, spate sparing; diurnal variations in abstraction rates, etc);

- specifying appropriate protection for fish (eg screens);

- renegotiating related existing licences which may be environmentally damaging, as part of the agreement package for the new licence.

The NRA has drafted a new abstraction licence charging scheme which reflects many of the above points, and is currently consulting widely with interested parties before coming to a firm proposal on the new scheme.

Licences are also usually granted for a specific purpose, with the intended use of the abstracted water being described within them. This implies that an abstraction licence is invalid if the water is being used for some purpose other than that specified. Also, the requirement to return used water to the river system at the point of abstraction can be written into the licence, although this is not always appropriate.

Applicants for new licenses should be encouraged towards efficient water use and, where appropriate, any undertakings they give in this area should be incorporated into the licence as enforceable conditions of abstraction. Thus, for example, an application to abstract groundwater to support a downstream river intake should be viewed more favourably (other things being equal) than a similar abstraction for direct supply, due to the water resources benefits which river support schemes produce, indirectly, for other users.

The range of opportunities to limit or curtail abstraction described above does not relieve the licensing authority of its overall duty to act responsibly and equitably. An appeals procedure exists to protect applicants from ill-judged refusals or unrealistic licence conditions.

Generally licences, once granted, remain in force until revoked. However, in certain cases a time limit may be appropriate on the licence as a whole or on certain of its conditions. This may occur particularly when:

- in the case of public supplies on large private use schemes, environmental monitoring is needed to establish the full impact of the abstraction, for example on estuarine water quality;
- resources are nominally licensed close to the maximum realistically available, but uptake is known to be low as a proportion of the total authorised quantity;
- in the case of private use, the operation for which water is needed is itself time-limited;
- use is for hydropower (in accordance with proposed national policy implementation guidance note);
- it is not clear that the licence will be fully used (eg for water bottling, or for a scheme of uncertain economic viability).

From the viewpoint of all water users, the prospect of a licence which remains in force longer than required ties up resources unnecessarily. Therefore, the licensing authority should make use of time limits for transient water needs, and should move to revoke licences which are not being used. However, time limited licences should not be used as a substitute for the correct sequence of planning, monitoring and assessment of potential impacts followed by promotion, licence applications and development.

4.3 Water Conservation Measures and Demand Management Options

4.3.1 General

In the context of the South West, four conservation/demand management techniques have been investigated.

- leakage control
- metering
- efficient water consumption
- drought restrictions

These are considered in turn below.

4.3.2 Leakage Control

The publication of the technical paper by the Water Research Association and the DOE/WRc standing Technical Committee Report 26 (8) has done much to assist water undertakings to standardise the methods and procedures for leakage detection and control.

A successful leakage control programme can only be satisfactorily carried out once the existing leakage levels are established. Active leakage control incorporates district and waste metering and, by monitoring flows in the distribution systems, allows the undertaker to locate and rectify the problem leakage areas more effectively.

Leakage rates are commonly expressed as litres per property per hour (l/prop/hr). Very low leakage levels of 5l/prop/hr are achievable in urban areas following the introduction of district and waste metering. However, an average level of between 6-8l/prop/hr is more realistic. These figures compare with existing estimated leakage levels of about 11 l/p/hr in the region, and a 2021 forecast of 6 l/p/hr. The optimum economic level of leakage attainable in a supply district will depend upon a range of factors which include the number of connections per length of main, the age, condition and working pressure of the service main and local ground conditions.

Leakage may be reduced further by the introduction of pressure control. Installation of pressure control valves into distribution systems, and conversion to variable speed pumps, enables mains pressure to be maintained at the minimum needed to meet prevailing demand. Thus pressure is reduced at night, when demand is low, with a corresponding reduction in the leakage rates and the incidence of mains bursts.

Three main elements need to be evaluated when undertaking a cost benefit analysis of leakage control, namely savings due to:

- reduction in water treatment
- reduction in water distribution
- deferment of capital expenditure

The water treatment saving is the easiest element to evaluate, since it can be directly related to the total volume of water supplied. The calculation of distribution savings is more difficult since it is highly site specific, whilst capital deferment is not only site specific but is further complicated by its dependence upon the accuracy of demand forecasts.

When considering leakage, the temptation to try to relate too closely leakage flow (measured in l/prop/hr) to unaccounted for water (UFW) (measured as a percentage of total demand) must be resisted. UFW is a balancing item between total volume of treated water supplied and the estimated water consumption; it incorporates all losses in the system which are either unmeasured or cannot be clearly estimated, including metering errors, mains bursts, illegal consumption etc as well as leakage. It is by nature sensitive to the accuracy of estimates of unmeasured domestic demand. For example a 10% variation in the 1990 estimate of per capita consumption for the region(1) would give either a +14% or -21% change in UFW values. For these reasons, leakage control targets given in terms of UFW should be treated with great caution.

SWWSL's leakage control policy is described in Section 2.4.5. With the introduction of more active leakage control measures, including district and waste metering and pressure reduction, SWWSL have stated that they are attempting to reduce the regional UFW level - estimated at 29% overall in 1990 (1) - to 16% by 1996. As commented previously, this is believed to be a very ambitious target, especially at zonal level.

SWWSL have recently revised the 1996 UFW targets for Allers and Pynes, and East Devon, increasing them by 4% and 2% respectively. More detail is required from SWWSL of the predicted reductions attributed to leakage control before detailed comment can be made, but there is some evidence that their forecasts of leakage are based upon simplistic assumptions.

It is understood that SWWSL's leakage control policy document and leakage measurement methodology have been externally audited and approved by the Water Research Centre. However, on the advice of WRc, SWWSL are currently reviewing leakage forecasts for all districts.

The implications of SWWSL leakage policy were difficult to analyse, since detailed information was not provided on the leakage assessment methods applied or the leakage target levels, expressed as l/prop/hr, in each strategic zone. The only available information was the target unaccounted for waste level in each WIS zone, expressed as a percentage of total demands. The supply zone UFW target levels shown in Table 4.1 have been calculated by the summation of WIS zone data.

Estimates of existing and forecast 1996 leakage levels in each supply zone expressed in terms of l/prop/hr have been calculated from UFW data (Table 4.2). The calculations are based on the following simplifications:

- leakage volumes equate to UFW volumes;
- a house occupancy rate of 2.5 persons per dwelling;
- leakage measured over a twenty hour day.

In comparison to the leakage levels quoted in Report 26 (8) these estimated levels are believed to be optimistic. In Table 1 part 2 of that report, typical levels of net night flows are given for large urban areas with combined district and waster metering leakage control. Depending upon the intrinsic leakage levels, the ultimate control levels range between 5l/prop/hr to 8l/prop/hr.

The South West Region is seen as a rural area with a number of large coastal towns. Any leakage control measures will be less effective than in a wholly urban zone because of the lower density of service connections per unit length of water-main.

For this reason the saving due to leakage control has been re-evaluated with an average target of 7l/prop/hr, which is classified by Report 26 as an achievable level for urban areas with medium to high intrinsic leakage levels. Although this is a generalisation, the choice of 7l/prop/hr is not arbitrary. Applying the simplified calculation from which Table 4.2 was developed, a leakage level of 7l/prop/hr is equivalent to an unaccounted water level of 18%; this corresponds to the average forecast UFW in the neighbouring and demographically similar Wessex NRA Region.

The changes in forecast demand in 1996 and 2021 due to an 18% leakage revaluation throughout the region are given in Table 4.3.

The revaluation given in Table 4.3 has been taken into account when developing strategies for the SWWSL supply area (Section 5).

4.3.3 Metering

The UK is the only country in the European Community not to meter domestic water consumption.

The Watt Report (9), published in 1985 reviewed the social, economic and engineering aspects of introducing metering in this country; among the identified advantages were:

- a more equitable system of charging for water than the present rateable value principle;
- an estimated 12% reduction in water usage, leading to lower operating and treatment costs and deferment of capital expenditure for resource developments;
- provision of a more direct measure of per capita demand, with consequent improved accounting for water and more efficient leak detection.

The water industry is prohibited from charging for water upon the basis of the rateable value of a property after March 2000. Of the available alternatives, including licence fees, property banding and bedroom or appliance charges, only metering allows charges to be directly related to customer consumption.

Through imaginative tariff structures, metering allows interaction and feedback between the customer and the Water Company. A tariff structure must be easily understood by the customer and be practical to administer. Within these constraints tariffs can be used to control consumption and help reduce seasonal and daily peak demands.

Predicting the water savings which metering might bring about, and therefore its economic viability, is an imprecise operation. As part of the assessment of costs and implications of general metering, the Department of the Environment, in association with the water industry, set up one large scale metering trial site on the Isle of Wight and ten (later eleven) small scale sites. The results of the national trial published so far show that customer reaction to metering is very site specific, and ranges between a 25% reduction to an increase in demand. Demand in the Isle of Wight has fallen by 15%, but this is thought probably not sustainable in the longer term as the novelty wears off. Interpretation by Southern Water of the interim results from the Isle of Wight trials suggests that a reduction of about 10% in the currently unmetered sector of demand would be sustainable in the longer term as a result of metering.

The potential to exert some control over the timing and extent of demand peaks is as important an aspect of metering as its impact on basic water consumption. This peak management option presumes careful structuring of the charging system in order to discourage excessive summer use in a drought year. Whilst it is acknowledged that it would be inappropriate to allow water to be treated as a market commodity, such as oil or metal, with prices rising and falling according to demand and supply, a facility could be designed to allow water prices to all users to rise by an additional fixed proportion in severe drought conditions. This would have to be linked to a similar increase in NRA abstraction charges so that the water companies would not gain from the water shortage, but monies would become available to cover costs of environmental protection, public relations campaigns and research.

A range of reductions of between 5% to 15% in the unmetered domestic portion of legitimate demand has been investigated, arising from the introduction of general metering. The results are shown in Table 4.4.

Metering is likely to reduce the seasonal peaking factor in addition to reducing annual average demand. The 2021 metering reductions have therefore been recalculated in Table 4.5 based upon:

- a 10% reduction in the unmeasured domestic component of annual average demand;

- a 20% reduction in the regional peaking factor

It is estimated from the above calculations that the introduction of metering and associated tariff structuring in the region would reduce the 'likely' forecast of peak period demand in 2021 by 57Ml/d.

4.3.4 Efficient Water Consumption

Total domestic demand represents approximately 50% of the public water supply in South West England. Domestic premises contain a variety of water using appliances, all fed from a pressurised plumbing system (Figure 12).

More efficient use of water in the home may be achieved by:

- public education

- redesign of appliances
- alterations to the plumbing system

The effects of public education initiatives are generally seen as useful in controlling water use during periods of temporary supply shortfall, but ineffective in the longer term unless coupled with other initiatives such as metering.

Examples of appliance design changes that could be made include:

- positive closure taps, which are held shut by the system pressure, and opened against it;
- smaller capacity and/or 'dual flush' lavatory cisterns
- dishwashers/clothes washing machines which store water for re-use in different cycles.

Modern wc's can work satisfactorily with a 7.5 litre cistern capacity, compared with the traditional 9 litres. This 16% reduction in water use would translate to a 5% reduction in use in the home (see Figure 12) or a 2½% reduction in overall demand, if fully utilised in all wc's in all new and existing homes. Similarly, if washing machines used 25% less water, the reduction in overall demand at full implementation would be 1½%.

Alterations to the plumbing system could lead to significantly improved home water efficiency, principally by re-use. For example, runoff from roofs could be stored for garden watering use, or bath and washing machine effluent ('grey water') could be re-used for wc flushing or, again, garden watering. Full re-use of such water would lead to a 30% reduction in domestic demand, although practical difficulties (e.g relative levels of bath outlet/wc cisterns) render achieving this level of reduction unlikely.

Of equal interest with potential reduction in demand through appliance redesign and replumbing is the speed with which such changes can be implemented. This will be driven by:

- appliance life
- consumer will for design changes

Washing machines last 5-10 years, while taps and wc cisterns may last much longer. Consumer will for design changes may be partially driven by social conscience about excessive water use, but is more effectively mobilised by volume related charging i.e. metering.

Replumbing of existing houses would be very costly and is unlikely to be undertaken purely for water economy. The changes could only be introduced in new homes or as existing ones are refurbished, and would thus take perhaps 50 years to implement fully. Again, volume related charging might speed up the process.

It is concluded that demand reduction due to more efficient water use is closely related to savings due to metering. To make an additional allowance for it could well entail double counting.

4.3.5 Drought Restrictions

During drought conditions, the water industry has traditionally relied initially on semi-voluntary methods of reducing demand with the introduction of hose-pipe bans and extensive publicity campaigns. Only if drought conditions worsen are physical controls such as pressure reduction implemented.

The frequency with which these measures can be introduced is defined in the target levels of service agreed between the water undertaker and OFWAT. In endeavouring to forecast supply deficits during a drought period, it could be argued that the effect of water restrictions should be taken into account. In this study such an approach has not been adopted, since the object is not to forecast system failure, but plan timing of resource development to avert failure.

The implementation and effects of drought restrictions on demand are likely only during the later stages of a drought during July/August/September. The analysis of the peak demand periods (Section 2) shows that the highest peaks occur during late spring and early summer; high demand peaks and drought restrictions are therefore unlikely to coincide.

For the above reasons, the possible reductions in demand due to drought restrictions have not been considered further.

4.4 Further Development of Existing Sources

4.4.1 General

The ways in which existing public water supply sources may be further developed include:

- increased integration;
- revised operating rules;
- pumped augmentation of reservoirs;
- enlarging reservoirs by increasing the height of the associated dams.

The scope of each of these is considered below.

It has already been noted that the output of the Otter boreholes, which has been in decline for a number of years, could be partially restored by redevelopment of the wellfield.

4.4.2 Increased Integration

The various SWWSL source groups are shown in Figures 7-10 and described in Section 3.2. There are at present 102 public supply sources in the South West. Of these,

- 45, with a total DRY of 106Ml/d, operate independently;
- 26, with an equivalent DRY of 44Ml/d, are operated in groups with a yield of less than 10Ml/d for each group;
- 13, with an equivalent yield of 93Ml/d, are operated in groups with a combined yield of more than 10Ml/d but less than 50Ml/d;
- 18, with a equivalent yield of 411Ml/d are operated in groups with a combined yield of more than 50Ml/d for each group.

The above assessment does not allow for any additional flexibility that may be afforded via inter-linkages in the treated water distribution system.

The advantages of source integration are that it:

- increases operational flexibility;
- permits greater conjunctive use of sources, which can lead to a yield gain.

It is often the case that peaks in demand in different supply zones do not coincide (see Table 2.4). Thus the increased flexibility of integration allows resources to be imported to a zone when it is experiencing a demand peak, or exported from it at another time, to help meet a peak in a different zone.

Although significant progress has been made in recent years - notably with the introduction of Roadford, which permits sources on the River Tamar, Dart and Torridge to be used conjunctively - there remains scope for further source integration in the South West. Reference to Figures 7-10 suggests that links could be provided between sources in:

(a) West Cornwall

(b) Taw and Torridge catchments

(c) South West Devon

(d) Exe Valley and East Devon

In addition, better linkage between the strategic zones may be worth considering.

In practice, links for (a), (b) and (c) are already largely afforded via the treated water distribution system. Some further scope for integration may remain, but the benefits will be marginal in strategic planning terms. In addition, new pipelines laid as part of the Roadford scheme help to integrate the North Devon and South West Devon zones with the extensive Tamar resources.

The most obvious area for improved integration is the Exe Valley, which has extensive resources but poor links to both East Devon and the Torbay area. There is known to be an early need for further resources to be made available in East Devon; in the short term, these could be met from the Exe system although in the medium/longer term, additional work would be needed (see Chapter 5). Ultimately, integration of Colliford with the Roadford zones, as well as Exe/East Devon/South West Devon links, is desirable.

4.4.3 Revised Operating Rules

Revised operating rules could include:

- reductions in summer abstraction, and increases in winter abstraction, to take advantage of an increased or newly introduced conjunctive use opportunity;
- changes to prescribed flow and/or other licence conditions governing abstractions;
- rededication of direct abstraction reservoirs to river regulation.

The commissioning of Roadford reservoir system affords the opportunity for operating rules to be changed at Lopwell (River Tavy), Torrington (River Torridge) and Littlehempston (River Dart) due to the support that it can provide to local supply system(s) in summer. The Roadford scheme has also led to the introduction of a significant new abstraction at Gunnislake on the Tamar. Such changes would allow increased winter abstraction, while limiting summer abstraction by means of an increase in the prescribed flow. It is understood that the licence for the Lopwell abstraction has already been changed to incorporate new operating rules, while those for Torrington and Littlehampston have yet to be revised.

The Roadford scheme has thus enabled operational flexibility to be increased, while the likelihood of summer flow depletion can be reduced.

A study of environmental implications of further development of the Exe catchment (10) concluded, inter alia, that the system yield could be increased by some 10Ml/d by lowering the prescribed flow at Thorverton, subject to a better understanding of the implications of such a reduction upon water quality in the Exe estuary. It is likely, however, that the prescribed flow reduction at Thorverton would be opposed unless it could be shown not to have significant adverse impact on the environment or on existing licensed and protected rights.

Elsewhere, it is considered unlikely that promotable changes to prescribed flow conditions or other operating rules governing existing sources will lead to a significant increase in yield. Indeed, the reverse is more likely, as discussed in Section 4.2; changes will more probably be driven by the need for low flow alleviation or other environmental mitigation, and may thus reduce the existing level of available resources.

The three largest reservoirs in the South West - Wimbleball, Colliford and Roadford, which together account for 84360 (74%) of the Region's 113,391Ml of net storage - are all used at least partially for river regulation. This mode of operation gives a higher yield per unit of storage than direct supply, other things being equal. Of the remaining 20 water supply reservoirs, 17, with a total storage of 22,315 Ml (20%) are used for direct supply, and 3, with a combined storage of 6,716 Ml (6%) are used for river regulation. Of the 17 direct supply reservoirs, the 4 largest are:

- Stithians (5,205Ml)
- Burrator (4,210Ml)
- Fernworthy (1,637Ml)
- Wistlandpound (1,550Ml)

In the case of Burrator, there is little to be gained from a change in operating rules, as the source is already operated conjunctively with the head-of-tide abstraction at Lopwell on the River Tavy.

Fernworthy operates conjunctively with the Kennick, Trenchford and Totteford (KTT) direct supply reservoirs. These sources are all located in the upper Teign catchment, and deliver a reliable yield of 23.9Ml/d from a total combined storage of 3491Ml. The Teign is a significant, but not major, river by South West standards, with a catchment area of some 380km^2. Reference to the Hydrometric Register and Statistics (11) suggests that conversion of the storage to river regulation, coupled with a tidal limit abstraction, could increase yield from the catchment by, say, 5Ml/d. It would also improve flows in an important salmon river known to have problems. However, the unit cost of the increment will be high due to the need for a new abstraction and treatment works, and for supplies to be maintained to areas in Central Devon currently fed directly from these reservoirs.

Conversion of Fernworthy to river regulation was considered in the Devon River Authority Section 14 Report (12). Again, it was concluded that it would not be worthwhile.

In considering river regulation, the potential impacts on existing and possible future abstraction in the regulated reach need to be identified. Augmented river flows attract non-consumptive abstractors but, if formerly deprived reaches are to be protected, abstractions need to be tied to prescribed flows which are based upon natural flows.

4.4.4 Pumped Augmentation

Pumped augmentation of a reservoir increases the inflow and thus the degree of confidence that it will refill within a given period following severe drawdown. It thus increases the reliable yield of a reservoir. Such increase will be significant if the reservoir is large and its critical period with natural replenishment is greater than twelve months - ie, it does not always refill naturally in the first winter following severe drawdown.

Pumped augmentation of Wimbleball has been actively considered (10,13) and would increase its yield by about 40Ml/d. To realise this, a new intake and pumping station on the main River Exe downstream of the reservoir, a 7km pipeline and miscellaneous works at the reservoir itself would be needed.

Pumped augmentation of Colliford Lake has also been mooted by SWWSL, although there are no data on how this would be done and what the yield increment would be.

For present purposes, an increment of 50Ml/d is assumed to accrue; detailed study would be needed before a firm figure can be deduced. The works needed to realise this increment would be similar in concept to those for pumped augmentation of Wimbleball.

The environmental implications of augmenting Colliford have not been assessed. However, the scheme is seen as likely to be very cost effective and at least worthy of further study.

By the same token, the yield of Roadford reservoir could also be increased through pumped augmentation. Again, no studies have yet been done, and the feasibility of such a scheme, and yield increment achievable, can only be determined following hydrological and environmental assessment studies.

Of the various changes to existing sources, pumped augmentation of the larger reservoirs offers most scope for increasing yields in the South West.

4.4.5 Increasing Dam Heights

The question of enlarging some reservoirs by increasing the heights of the associated dams was addressed in the Devon River Authority Section 14 Report (12). This suggests that it would be possible to raise the following dams:

- Avon, by 4m or 7.9m, to increase yield by 5.4 or 10Ml/d;
- Fernworthy, by 6.1m, to increase yield by 6.8Ml/d.

However, the report concluded that raising was not attractive in these cases, since it would be disruptive and costly, and the associated yield gains would be small.

Since the Section 14 Report was completed, Wimbleball dam has been built, with specific provision in the design of the foundations for a future raising of up to 1.5m. The Exe resources study (10) assessed the likely yield increment from such a raising to be 67Ml/d, provided a pumped augmentation scheme were already in place. A 5m raising was also considered, for which a 93Ml/d yield increment was deduced. It is important to note that the present limiting factor on Wimbleball yield is not reservoir capacity, but reservoir inflow; thus increasing the capacity will be more effective if the average rate of inflow has already been increased by pumped augmentation.

Considerable opposition to raising Wimbleball is likely, as it will disrupt the present harmony between land, trees and water around the reservoir's edge. The worst effects of this could be mitigated, but it would take several years for a new harmony to become established.

4.5 Development of New Sources

4.5.1 General

Before the introduction of any new major strategic option, a policy of good housekeeping should be initiated. The aim of good housekeeping is to realise the full potential of the existing resources and provide the foundation for an effective supply system. Good housekeeping may include all of the following elements:

- leakage control (both raw and treated water);
- increased conjunctive use of resources;
- increased integration of the supply system;
- improved effluent discharge standards to facilitate possible indirect reuse;
- using "state of the art" techniques to control abstraction accurately.

These opportunities should be seen to have been fully explored before embarking on a resource development programme. Without this prerequisite, there is a danger that the supply system will grow in a piecemeal and random fashion rather than in a strategic manner.

4.5.2 Conventional Schemes

The scope for new water resource schemes in the South West has been the subject of several previous studies including those carried out by:

- Devon and Cornwall River Authorities, in pursuance of their duties under Section 14 of the Water Resources Act, 1963 (12,14);

- Halcrow "Water Supplies for South West Devon" (15) (for Devon River Authority);

- MRM Partnership, for SWWSL - various investigations relating to future water supplies in East Devon generally, and to the River Axe pumped storage scheme in particular (16).

The reports of these studies have been reviewed in order to identify the more promising potential schemes; however, some caution is needed, as all but the MRM work was carried out some 20 years ago.

As noted elsewhere, there is no overall shortage of gross water resources in the South West on a year-round basis. However,

- there is little or no potential for further groundwater development in a strategic sense;

- summer flows are relatively low, so that unsupported river abstractions can provide little in the way of drought reliable yield.

Thus conventional water resource development opportunities are firmly focused upon providing more storage - ie, constructing new dams and reservoirs. A number of promising reservoir sites have been identified in the course of the above listed studies, and , while some have since been discarded on grounds of cost or development of an alternative nearby, good prospects apparently remain in East, North and South Devon and parts of Cornwall. These have yields ranging from a few tens to nearly two hundred megalitres per day (Ml/d).

Any new reservoir scheme will have to be fully justified to the public, and carefully promoted. The words of the Water Resources Board in the late 1960's in relation to the South West are relevant:

"The problem is not one of shortage of water resources but rather of a multiplication of possible sources and sites, many of them attractive technically but all involving strong opposition from other interests. They highlight the conflict of interest between agriculture on the one hand and the preservation of the natural landscape on the other."

Resistance to new schemes on environmental grounds is likely to be even more concerted than it was 30 years ago, and no new development should be considered unless it can be shown to be less damaging than using existing resources to their full potential.

It is suggested that any new reservoir should be used for river regulation to a head of tide abstraction rather than for direct supply. Regulation schemes are more efficient in water resource terms, since they overcome the limitations on consumptive up-catchment abstraction rates and periods of use; these limitations arise from the need to protect rights associated with established, high rate, non-consumptive abstractions further downstream. In addition, properly formulated regulation schemes can bring about a number of indirect water resource and environmental benefits at times of low flow.

Besides providing more storage, one other potential conventional scheme was identified. This relates to an unsupported abstraction on the Fal, which is a relatively large river not utilized at present due to water quality problems associated with pollution from the china clay industry. In recent years, however, there has been a marked improvement in the river Fal, and direct abstraction at the tidal limit could be envisaged in the future.

4.5.3 Re-use of Effluents

Re-use of effluents for potable water can be either

- direct, whereby treated effluent is returned to the supply system via either a pipe to pipe connection to a water treatment works or discharged to a direct supply raw water reservoir;
- indirect, whereby treated effluent is discharged to a natural water body (an aquifer or a river system) and is subsequently re-abstracted and treated for water supply.

A re-use scheme delays the return of the water to the sea by creating a loop in the hydrological cycle, and providing a base flow increment from which increased abstractive yields can be derived.

There are no examples of direct re-use schemes at present in the UK, and overseas they are rare. Although technologically feasible direct re-use leaves little room for human error. If a mechanical breakdown or operational error occurs, contaminated water may pass quickly into distribution without the opportunity to isolate the system. It is felt any proposals for direct re-use in the South West would be vigorously contested by the public, on the basis of the associated perceived risks to health.

Indirect re-use is practised to a greater or lesser extent in all the NRA regions. It is most prevalent in the highly populated regions of our larger rivers systems such as the Thames and the Severn, where indirect use has evolved with the ever increasing demand for public water supplies. Here treated effluent from inland conurbations is discharged to river systems which have public supply abstractions further downstream. The intervening length of river provides a temporal and spatial buffer against treatment failure.

In the South West there is little indirect reuse even on the region's major rivers, the Tamar, Torridge, Taw and Exe. The region's urban population is concentrated in the coastal cities and towns such as Plymouth and Exeter, which draw their water from the river system upstream and discharge their effluents to tidal waters. Tiverton is one of the few significant inland towns on a major river, and treated effluent from the town is discharged to the Exe upstream of the principal intakes which serve Exeter. Elsewhere, however, inland populations are low, and although effluent is discharged into the water courses, the quantities involved are small. It is stated NRA policy to encourage location of river abstractions close to the tidal limit, so that their environmental impact is minimised. The NRA are thus encouraging the development of indirect re-use in the Region's rivers.

In repositioning the abstraction points lower downstream the water undertakers have to maintain the water quality by either:

- increasing expenditure on water treatment (front end treatment), or

- improving the quality of upstream effluent discharges standards (back-end treatment)

For a re-use scheme to be operated successfully and safely it is necessary for a single undertaking to have control over both effluent discharges into, and public water supply abstraction from, the river system. Without this power an integrated re-use scheme balancing front end and backend water treatment cannot be developed.

As discussed, a large proportion of the region's population lives near to the coast. It has been estimated that 52% of the Region's public water supply (including leakage) passes directly to the saline environment. Instead of discharging to the sea, the effluent can be re-used by treating it to a high standard and actively pumping it above the abstraction points and augmenting natural river flows downstream of the point of discharge.

In ascertaining the feasibility of any re-use scheme certain key factors have to be addressed:

- composition and volume of effluent discharge, and the level of required treatment;

- monitoring of discharge quality;

- long-term health effects;

- nature of receiving water body;

- public acceptability.

Untreated effluent from large urban areas is a combination of domestic and trade discharges. The composition of the effluent will determine whether it is economically viable or even feasible to treat it to a high standard necessary for re-use. Given enough investment, most effluents can be treated to a near potable standard; however, no matter how sophisticated the water treatment, there will always be a residual level of contaminants which cannot be removed.

In initiating a re-use scheme, a decision must be made on the level of contaminants which would be acceptable without causing foreseeable long term public health problems. Many of the contaminants found in effluent are known to have harmful effects at high doses, but as yet little is known about the long term effects of smaller doses as found in treated effluents.

The three classes of contaminants which are of specific concern when considering a re-use scheme are viruses, organic contaminants and heavy metals. There is at present no reliable technology which can totally eliminate either viruses or organic compounds including pesticides.

Careful monitoring of contaminants of the 'treated' effluent is required, especially where dilution is limited. Unfortunately there is at present a deficiency of reliable and rapid analytical tests for many of the potentially dangerous contaminants which allow timely corrective measures to be made.

The benefit of an indirect re-use scheme is that the effluent is diluted, mixed and undergoes some measure of natural purification. In the South West Region, the rivers are characterised by rapid run-off spate events and relatively low summer flows. The retention time and natural cleansing period of effluent in a spate river is far less than in a lowland river of similar length, and thus any effluent discharged into the spate river would have to be treated to a higher standard.

In promoting such a scheme, one of the most important primary concerns is to gain the public's confidence in and acceptance of re-use. In the Thames region effluent re-use has been accepted by the general public as an inevitable consequence of urban living. However, whether this view will remain as people become more aware of water quality and environment issues is uncertain. A large publicity campaign would inevitably be required in order to assuage public opinion prior to introduction of a specific major re-use scheme in the South West.

Thames Water Utilities Limited have recently abandoned their plans to re-use effluent from the Beckton sewage treatment works and transfer it to either the River Lea or Lea reservoirs, because of foreseen public objections.

Indirect re-use is a strategy which allows present resources to be used more efficiently by increasing the net utilization of the resource. The main problem of re-use generally is the uncertainty surrounding the long term health effects of residual contaminants in treated effluents; in the South West extensive collection, diversion and pumping of effluent from the coastal towns would be needed, as well as improved treatment, in order to provide a significant yield in strategic planning terms.

For these reasons, effluent re-use is seen as an expensive solution to supply deficit problems in the South West.

4.5.4 Desalination

Large scale purification of salt water is basically not a problem of feasibility but of economics. The main cost element in water production by desalination relates to the power consumed in the process. The environmental implications of the energy consumption, and of by-product disposal, are also unfavourable. Only where cost and environmental considerations are secondary due to lack of resource availability, therefore, is desalination at present a conceivable option.

The two most commercially important desalination processes are Multi-staged Flash distillation (MSF) and Reverse Osmosis (RO). Production costs for desalination vary depending upon the plant size and quality of the source water. A review of recent desalination feasibility studies in the UK show a range of production costs between 70p/m^3 to 90p/m^3. Studies have indicated that combining a desalination plant with existing power generation facilities lower production costs can be achieved. The plants power costs can be reduced by utilization of the power plants exhaust steam and the off-peak production of electricity. The MSF process can be adapted further to enable the plant to burn domestic waste and thereby obtaining a cheap power source and revenue from waste disposal.

South West Water recently commissioned a desalination feasibility study to investigate the possibility of establishing a plant in the East Devon supply zone (17).

The report concluded that the most appropriate desalination option was RO plant located at the coastal town of Seaton, and used to meet peak summer demands. A range of plant capacities of 5-28 Ml/d was reviewed and a production cost of 70p/m^3 (excluding capital costs) was estimated for a 22.5Ml/d plant. This may be compared with the typical cost of water supplied by impounding reservoirs, as computed for the National Resources Strategy study(1), of about 25p/m^3. In work carried out for SWWSL in connection with the proposed Axe scheme (17), the high production costs of desalination precluded it as a credible water resource strategy option.

In comparing the two types of desalination plant, the SWWSL report outlines the advantages of the RO plant in requiring lower power inputs and having fewer environmental problems associated with brine disposal. The report does not fully address the disadvantages of an RO plant if it is planned to be mobilized only during periods of peak demand. Thus it may be expected to be even more costly than the report suggests.

4.6 Resource Options Specific to Wessex Water

Resources development options within WW's Avon/Somerset supply area which have not been covered in principle in the preceding sections include:

- groundwater development;

- a share in further development of Wimbleball, on the same basis as at present;

- further exploitation of the River Avon in the vicinity of Bath;

- importing water from Severn-Trent or Welsh Regions.

Schemes in the Somerset lowlands, while technically possible, have been shown to be very costly.

The scope for further groundwater development is understood to be limited, and this option has not been pursued to present purposes.

WW have a 46% share in the present Wimbleball reservoir. They would wish to see that holding carried over to any further development of the facility that may occur, although the legal basis for doing so is poorly defined. In addition, since their supply from the reservoir is direct, rather than via river regulation, any increase in WW take would lead to a disproportionate reduction in the water available to SWWSL.

It is shown in the Exe Resources EIA study support (10) that gaining 17Ml/d at Newbridge on the Taw, via abstraction at Exebridge on the Exe, leads to a yield reduction of 22Ml/d at Allers and Pynes water treatment works. Exebridge is close to Wimbleball, but benefits from a large natural catchment, as well as regulation releases from the reservoir. For present purposes, however, it seems reasonable that for every 20Ml/d direct supply from Wimbleball to WW, the SWWSL river regulation yield would need to be reduced by 30Ml/d.

It should also be borne in mind that transfers from Wimbleball to WW represent a 100% resource loss from the Exe basin. It is acknowledged that most of the water supplied by SWWSL from the Exe via Pynes is probably discharged to tidal waters after use. However, the same is not true of water supplied via Allers which represents some 30% of the Exe-derived SWWSL supply. If it is assumed that 50% of the Allers, and 0% of the Pynes, supply can be re-used, then the SWWSL consumptive use of Exe-derived water is 85%. On this basis the resource value to SWWSL of the 30Ml/d quoted in the preceding paragraph is thus in fact 35Ml/d.

Wimbleball derived water supplied by Wessex is used in Taunton, the Somerset lowlands towards Yeovil and along the North Somerset coast to Hinkley Point Power Station. Much of this water is discharged beyond any abstraction points, and consumptive use for public supply is estimated to be at least 95%, giving the 20Ml/d notional Wimbleball supply quoted above a resource value to WW of 21Ml/d.

It is seen, therefore, that the direct supply to WW from Wimbleball represents less efficient resource use than the river regulation supply to SWWSL.

In the Bristol Avon Study (18), (carried out in 1985) various schemes for supplying 75Ml/d or 150Ml/d jointly to WW and Bristol Waterworks Co (BWW) are compared. It was concluded that pumped augmentation of Chew Valley Lake (without or with dam raising) or a new reservoir scheme, were worth studying in more detail.

Chew Valley Lake is owned and operated by BWW, and any scheme based upon it to benefit WW would be dependant on agreement between the organisations. An environmental assessment of the pumped augmentation has been carried out for BWW, and is understood to have been cautious but positive about the proposal. However, BWW have since opted to further development of Severn-derived water via their works at Purton, on the Gloucester-Sharpness canal.

The new pumped storage reservoir could be developed independently of BWW, and in the 1986 study a yield of 150Ml/d was deemed possible; this was subject to further investigation which has not been carried out. In the meantime, WW have chosen instead to develop a pumped storage scheme based on the existing, but relatively small, Monkswood reservoir, north of Bath; existence of the latter scheme may reduce the feasible output from the alternative mooted in 1986.

The concept of a river abstraction near Bath to support pumped augmentation schemes is reasonably sound in resource terms, since it would be well down the catchment. Ideally it should be located downstream of Saltford, in order to take advantage of the effluent returns via the large sewage treatment works there; this would probably require a substantially improved level of treatment at the works. Previous assessments of potential schemes have assumed an intake upstream of Saltford, as will be the case with the Monkswood scheme.

A major river abstraction at Bath also affords the opportunity to convert the direct supply groundwater sources on the upper (Malmesbury) Avon to river regulation, which could help to overcome perceived low flow problems, and possibly increase available net yield as well. However, this would require major rezoning of the potable water supply system in the Malmesbury area.

Importing water to the WW supply area from Severn Trent or Welsh Regions was shown in 1986 to be more costly than the local options discussed above. In resource terms, it would be better than importing water from Wimbleball, since water would be abstracted from the lower end of a catchment (Severn) rather than from the upper part (Exe).

TABLE 4.1 SWWSL EXISTING AND TARGET UNACCOUNTED FOR WATER LEVELS
(expressed as a percentage of total demand)

Supply Zone	1991	1996	2001	2011	2021
Colliford	27	13	13	13	13
N Devon	28	14	13	13	13
Plymouth	21	18	17	17	18
S W Devon	28	16	16	16	16
Allers and Pynes	27	22	22	22	22
E Devon	29	20	20	20	20
Region	26	16	16	16	16

TABLE 4.2 ESTIMATE OF EXISTING SWWSL SUPPLY AREA LEAKAGE LOSSES AND 1996 FORECASTS
(expressed in terms of l/prop/hr)

Supply Zone	Existing Losses 1991		Forecast Losses 1996	
	UFW Ml/d	Equiv. Leakage l/prop/hr	UFW Ml/d	Equiv. Leakage l/prop/hr
E Devon	10.56	11.7	6.93	7.4
Allers and Pynes	16.01	11.4	13.22	9.2
Roadford				
S W Devon	25.30	11.1	13.29	5.6
Plymouth	19.13	7.5	16.94	6.4
N Devon	19.33	12.8	8.72	5.5
Colliford	40.04	11.3	18.57	4.9
Region	130.37	10.7	77.66	6.1

TABLE 4.3 SWWSL SUPPLY AREA LEAKAGE REVALUATION

Supply Zone	Demand Changes due leakage revaluation Ml/d	
	1996	2021
E Devon	-0.9	-1.2
Allers and Pynes	-2.9	-4.0
Roadford		
S W Devon	+2.0	+2.8
Plymouth	0	0
N Devon	+3.1	+6.0
Colliford	+8.5	+13.2

Note: The above reductions relate to annual average demand. For peak period demand reductions they should be multiplied by the peaking factors (see Section 2).

TABLE 4.4 REDUCTIONS IN SWWSL AVERAGE ANNUAL DEMANDS DUE TO METERING
('likely' forecasts, with leakage targets achieved)

Row Ref	Item	Supply Zone						
		Colliford	N Devon	Plymouth	SW Devon	Allers	E Devon	Total
1	2001 - Forecast total demand (Ml/d)	154	70	100	90	63	37	514
2	2001 - Forecast UFW (Ml/d)	20	9	18	14	14	8	83
3	2001 - Forecast measured demand (Ml/d)	47	28	23	25	19	9	151
4	2001 - Forecast unmeasured demand (Ml/d)	87	33	59	51	30	20	280
5	2001 - Reduction in total demand forecast due to metering (Ml/d)							
	(a) 5% of row 4	4	2	3	3	2	1	14
	(b) 10% of row 4	9	3	6	5	3	2	28
	(c) 15% of row 4	13	5	9	8	5	3	42
6	Revised 2001 forecast with 10% reduction in unmeasured demand due to metering (row 1 - row 5b) (Ml/d)	145	67	94	85	60	35	486
7	2021 - Forecast total demand (Ml/d)	216	96	124	117	82	48	685
8	2021 - Forecast UFW (Ml/d)	28	13	22	18	18	10	109
9	2021 - Forecast measured demand (Ml/d)	65	36	26	32	23	11	197
10	2021 - Forecast unmeasured demand (Ml/d)	123	47	76	67	39	27	379
11	2021 - Reduction in total demand forecast due to metering (Ml/d)							
	(a) 5% of row 9	6	2	4	3	2	1	18
	(b) 10% of row 9	12	5	8	7	4	3	39
	(c) 15% of row 9	18	7	11	10	6	4	56
12	Revised 2021 forecast with 10% reduction in unmeasured demand due to metering (row 7 - row 11b) (Ml/d)	204	93	116	110	78	45	646

TABLE 4.5 ESTIMATED METERED PEAK PERIOD 2021 DEMAND BASED ON SWWSL LEAKAGE TARGETS

Supply Zone	Metered AA demand Ml/d (10% reduction)	Unmetered Peaking Factor	Metered Peaking Factor	Metered PW Demand Ml/d	Reduction in PW Demand Ml/d
E Devon	45	1.15	1.12	50	6
Allers and Pynes	78	1.06	1.05	82	4
Roadford					
S W Devon	110	1.19	1.15	127	12
Plymouth	116	1.07	1.06	123	10
N Devon	93	1.07	1.06	99	6
Colliford	204	1.15	1.12	227	21
Region	645	1.11	1.09	703	57

5 RESOURCE DEVELOPMENT STRATEGIES

5.1 SWWSL Supply Area

5.1.1 Forecast Deficits

Various points emerge from the discussion in earlier chapters on demand forecasting, resource yields and development options. In particular:

(a) demand forecasting, particularly for privately abstracted water, is necessarily uncertain;

(b) the current level of drought reliable yield may be cut back in the future due to environmental considerations;

(c) the leakage targets published by SWWSL appear to be optimistic when judged against relevant literature.

To accommodate these points, SWWSL supply area deficits have been deduced for two alternative scenarios, as follows:

- Scenario 1
  - 'likely' forecast levels of pws demand;
  - no future cut-backs in existing source yields due to environmental factors (see Table 3.4);
  - published leakage targets achieved in full.
- Scenario 2
  - 16Ml/d cut-back in reliable yields of existing sources across the region, due to low flow problems generally
  - a further 20Ml/d cut-back in reliable yields, reflecting an increase in reservoir compensation flows where necessary to achieve a common standard of Q_{95}
  - an increase in 'likely' demand of 17Ml/d in 2021, due to a failure to meet published leakage targets

The justification for the Scenario 2 yield reductions is set out in Section 3.6, and that for leakage achievement standards in Section 4.3.

The deficits deduced in this way are presented in Tables 5.1 and 5.2 for Scenarios 1 and 2 respectively, and strategies to overcome them are presented in Sections 5.1.2 and 5.1.3 below.

In estimating the deficits shown on Tables 5.1 and 5.2 and preparing the strategies, it has been assumed that a new development should be commissioned when peak 4-week demand x 1.05 equals existing available resources. Thus a margin of 5% of demand is built into the strategies, to accommodate problems which may arise from unexpectedly rapid demand growth, further environmental cutbacks, global warming etc. As noted in Section 4.1, this effectively brings the deficits into line with those pertaining to the "high", rather than "likely", demand forecasts. Using the "low" forecasts and a 5% planning margin, the 2021 Scenario 1 equivalent deficit would be 94Ml/d.

5.1.2 Strategy for Scenario 1

Scenario 1 2021 deficits are (Table 5.1):

- Colliford : 57Ml/d
- Roadford : 63Ml/d
- Wimbleball : 39Ml/d
- SWWSL supply area : 152Ml/d

These figures include a 5% planning margin on demand. The regional figure is less than the sum of the zonal figures because of the peaking factor "gain" which applies to the larger area, assuming sources within it are fully integrated.

Demand versus available resource graphs for the three strategic reservoir zones and for the region as a whole are shown in Figures 13-16. It may be deduced from these and from Table 5.1 that Colliford and Roadford zones will remain in surplus to beyond 2006, but a deficit will have arisen in Wimbleball zone by 1998.

If the Wimbleball zone is broken down into Allers and Pynes and East Devon subzones, there are apparently already peak 4-week deficits in the latter area, which are offset by surpluses in Allers & Pynes (see Figure 15).

As noted in Chapter 4, the guiding principles for a sensible strategy for responding to demand growth should embrace the following, in descending order of preference:

- improved accounting for water
- integration of sources
- modifications to existing schemes
- new developments

Under Scenario 1, it is assumed that the scope for improved accounting for water is substantially taken up, by virtue of the fact that the published leakage targets are achieved. However, it should be noted that the Wimbleball zone targets are not particularly ambitious (see Section 4.3.2); if the targets for that zone were brought into line with expectations deduced from published data, the zonal consumption in 1996 would be reduced by 4Ml/d. Of this, 3Ml/d would be "gained" in the Allers and Pynes sub-zone, and 1Ml/d in East Devon; thus improved accounting for water will not be itself overcome the pressing problems in that sub-zone.

Further integration of sources would be valuable at two levels. In the short term, better links between the Exe valley and East Devon will help to contain present problems in the latter area. In the long term, links between Wimbleball and Roadford zones (via South Devon), and Roadford and Colliford zones will reduce the deficits from the sum of the parts towards the overall regional figure - that is, from 159Ml/d to 152Ml/d in 2021. This gain is a reflection of the lower peaking factors which apply to larger supply blocks.

There are a variety of resource development options in Wimbleball zone, entailing both modifications to existing schemes and new projects. Many have been studied to pre or full feasibility level. In addition, the option exists to transfer water eastwards from Roadford zone, which remains in surplus until about 2006 under Scenario 1. Although improved source integration is an essential element of any development strategy in the South West, moving water eastwards into the Wimbleball zone is seen as an inappropriate solution to the early problem there, since:

- by the end of the planning period, a significant deficit will have built up in Roadford zone, so that a transfer eastwards could not be sustained and may even need to be reversed;
- Wimbleball alone of the three zones has further potential development schemes which have been studied in some detail and may thus be expected to have a shorter lead-in time;
- the Roadford development is in any case itself very new,and a very compelling case would be needed to hasten the need for further resource developments in this zone.
- the potential for development in Colliford zone is limited and is unlikely to meet forecast deficits in 2021. Any surplus in Roadford would be better utilised by transferring it westward rather than to the east.

The local development options in Wimbleball zone are summarised in Table 5.3. They assume that the Exe-Taw transfer, for which SWWSL hold a licence until 1995, is discontinued. It is shown in the Exe Resources EIA report (10) that some 5Ml/d extra yield can be obtained from the Exe system without the Taw transfer. It can be seen from Tables 5.1 and 5.2 that, in the period 1996-2001 when the impact of continuing or discontinuing the Taw Transfer would occur, peak period regional planning demand is growing at about 9Ml/d per year. Thus, if the Taw transfer is retained, deficits would acrue about six months earlier than is assumed under Scenarios 1 and 2.

As noted in Section 4.4.4, pumped augmentation of Colliford and Roadford lakes represents the logical next strategic developments in these two zones. Neither scheme has yet been studied in detail, but for present purposes the assumed yield gain from each is 50Ml/d. This is larger than the basic 44Ml/d gain from augmenting Wimbleball, since Colliford and Roadford lakes have greater capacity (28540 and 34500 Ml respectively, compared with Wimbleball's 21320 Ml). It is emphasised that study is needed to confirm these figures. In particular, the Colliford gain might be less than the available storage would suggest; the Fowey catchment is already committed to a relatively high level (see Table 3.2), although it may be possible to augment the reservoir from a neighbouring river system.

The Scenario 1 aggregate zonal deficit of 159Ml/d may be substantially met by the following developments (see also Figures 13 to 17):

Zone	Development	DRY Increase	Cumulative DRY Gain	Needed by
Wimbleball	Otter boreholes redevelopment	7	7	1999
	Wimbleball augmentation	37	44	2001
Colliford	Colliford augmentation	50	94	2006
Roadford	Roadford augmentation	50	144	2011
Wimbleball	Integrate Wimbleball and Roadford zones +Creedy OR Culm abst^{n}	7	151	2012

All of these developments comprise essentially modifications to existing schemes, rather than new developments. They are thus likely to represent relatively good value for money; in terms of cost per Ml/d of yield gain the discounted cost of Wimbleball pumped augmentation was estimated at £0.23m per Ml/d in 1989 (equivalent to £0.25m/Ml/d in 1992). However, it should be noted that in many cases some further work is necessary to assess the prospects of successful promotion (see for example, Table 5.3).

Whilst opportunities exist in the South West to increase yields in this way subject to environmental impact assessement, there seems little point in introducing extensive metering. This option could reduce the 2021 peak period deficit by 57Ml/d, but was shown to be relatively expensive in the recent national water resources study (£2.7m - £12m per Ml/d of water saving, according to assumption made about level of demand reduction achieved) (1).

The yield from Wimbleball pumped augmentation has been reduced from 44 to 37Ml/d to allow Wessex Water to take their current full authorised quantities, but it has been assumed that they would not receive a share of the augmentation gain. Inclusion of a further 7Ml/d (Creedy or Culm) reflects the identified scope for up to about 23Ml/d of further development in the Exe catchment (schemes a, d and e on Table 5.3).

The schemes identified above fall 7Ml/d short of providing a 5% planning margin on the sum of the zonal demands. To meet this requirement, a further scheme will be needed. This scheme could be:

- widespread metering of domestic properties;
- an Axe based pumped storage scheme or raised Wimbleball;
- a new development in Colliford zone;
- a new development in Roadford zone;

together with zonal transfers as appropriate.

The current perception is that metering of domestic properties is a relatively expensive means of reducing water demand in terms of cost per Ml/d saved (see above). Unless this changes, or other considerations lead to the introduction of metering, development of local resources is likely to continue. Proper use of water resources may impose the need at least to meter the distribution system more extensively, if not to meter domestic properties; the resource implications of this are closely allied to those of improved leakage control. Widespread domestic metering would reduce the Scenario 1 2021 planning deficit by 57Ml/d, obviating the need for one of the reservoir augmentation schemes.

An Axe-based scheme of at least 13Ml/d yield is sufficient for the deficit outstanding, although remote from the areas where it occurs. It would serve the purpose, since water could be displaced westwards between adjoining zones, but it has no apparent advantage over a similar sized scheme in West Devon or Cornwall.

If a part of the enhanced Wimbleball yield is diverted to WW, SWWSL's gain from the scheme will be reduced. A 12Ml/d additional supply to Wessex would reduce SWWSL's gain from 37Ml/d to perhaps 19Ml/d (further study is needed to confirm this). Under these circumstances an Axe-based scheme yielding 25Ml/d would be just adequate to close the planning deficit. The most appropriate solution then is probably to raise Wimbleball, so that both parties can benefit by significant amounts.

For present purposes, it is assumed that enhanced yield from Wimbleball is not shared with WW and that the planning deficit is met by further development in the Exe valley, pumped augmentation of the three strategic reservoirs and, finally, development of an Axe based pumped storage scheme in 2017 (see Figures 13-17). In practice, the decision on whether to pursue an Axe scheme could be deferred until nearer the time, when better data are available on demand growth patterns, metering costs and effects, environmental cut-backs and source yields.

5.1.3 Strategy for Scenario 2

The demand/resource balances for Scenario 2 are plotted on Figures 18-21 and the deficits including a 5% planning margin on peak 4 week demand are shown in Table 5.2. The 2021 figures may be summarised:

• Colliford	88Ml/d
• Roadford	92Ml/d
• Wimbleball	36Ml/d
• SWWSL Supply Area	208Ml/d

Again, the sum of the zonal figures exceeds the regional figure due to peaking factor "gain".

The Wimbleball figures mask the more serious position in East Devon, which is offset by a temporary surplus in the Allers and Pynes area.

If the basic demand response framework (improved accounting integration, modifications to existing schemes, new developments) is applied to Scenario 2:

- the premise is that improved accounting does not deliver the benefits anticipated by SWWSL for Scenario 1;
- the case for integration of zones has been made for scenario 1, and is potentially even more valuable here;
- modifications to existing schemes, as described in Section 5.1.2, could provide an additional yield of about 151Ml/d.

Thus the sum of the zonal deficits could be reduced by 151Ml/d, from about 216Ml/d to about 65Ml/d, without having to resort to a wholly new development.

The remaining deficit could be overcome by either:

- a new scheme, or
- the introduction of metering.

Possible new schemes include an Axe based pumped storage scheme, and other reservoir options such as those identified in the River Authority Section 14 report of the early 1970's.

It is clear from Figures 18-21 that:

- East Devon should be more fully integrated with Allers and Pynes as a matter of urgency;

- the Otter boreholes upgrading scheme should be investigated as a matter of urgency;

- Colliford pumped augmentation should be commissioned, and Roadford and Colliford zones integrated, by 1999;

- Roadford pumped augmentation should be in place by 2005;

- Wimbleball pumped augmentation should be in place by 2000;

- further development is needed for Roadford and for Colliford by 2014.

The timing of development can be changed by making greater use of inter-zonal transfers. By advancing the date of the Creedy/Culm abstraction and transferring water to Roadford zone, augmenting Roadford can be postponed until 2007.

The Roadford zone new development has been postponed until about 2014 by introducing the Culm or Creedy schemes and by redirecting some of the yield from Pynes to South West Devon. This would not overcome the Colliford problem after 2014, or solve Roadford zone's deficits with the required margin up to 2021.

Alternatively, a larger scheme to meet the needs of both Colliford and Roadford may be more appropriate. In this way, the need to promote two major "green field" schemes in the planning period can be avoided.

If the Culm/Creedy is excluded, a 72Ml/d scheme would be required in order to achieve the required 5% margin throughout the SWWSL supply area. A review of studies from the early 1970's suggest that there are potential schemes with yields in excess of this amount in North and South Devon, and mid Cornwall. However, such potential schemes will need up to date investigation based upon current criteria in order to confirm their viability.

Raising Wimbleball by 5m is a further option, although this is remote from the main areas of need.

Alternatively, the introduction of metering could reduce 2021 peak demands by up to 57Ml/d, reducing the size of new scheme required to 15Ml/d. This is less than the estimated peak output from an Axe based scheme (22Ml/d). However, in view of the uncertainty which surrounds metering at present in terms of potential savings and likely costs, it would be unwise to rely upon this as a firm option at present.

For present purposes, it has been assumed that Scenario 2 deficits could be met by improved integration, Otter valley wellfield redevelopment, further development in the Exe valley and pumped augmentation of the three strategic reservoirs, followed by a major new reservoir with a nominal yield of 100Ml/d in the Roadford strategic zone, commissioned in 2014 (see Figures 18-22).

5.1.4 Private Abstractions

The most significant potential growth area in private abstraction in the SWWSL supply area is spray irrigation. Here daily demand could increase by between 30 and 190Ml/d (Table 2.14). These quantities are significant; especially if the growth occurs in areas where irrigation is already concentrated - the lower Exe/Clyst/Otter catchments and West Cornwall (see Section 2.6.2).

Clearly, growth in irrigation demand will need to be closely monitored and, if necessary, new licence applications refused unless the promoter is prepared to build storage and confine abstraction to the winter months. It is understood that, in the main River Exe at least, this situation has probably already arisen.

An alternative might be to dedicate some storage in the larger reservoirs to river support for irrigation. However, this would only benefit those irrigators downstream of such a reservoir.

Other consumptive components of private demand are not expected to grow significantly, and special measures beyond those routinely used in determining licences should not be necessary.

5.2 WW Supply Area

Only one demand scenario has been considered for the Somerset/Avon zones of the WW supply area, although the sensitivity of the strategy developed to meet it has been tested against the 21Ml/d "low flow debit" reduction in resources discussed in Section 3.6.

The basic deficits are set out in Table 5.4. These show that a deficit will arise in about 2011, growing to 27Ml/d by 2021. If a planning margin of 5% of demand is applied, a new resource yielding 46Ml/d will be needed, from about 2004. As noted in Section 4.1, this is broadly in line with the "high" forecast deficit. The "low" forecast deficit, including 5% planning margin, would be 24Ml/d.

It is possible that a proportion of the 24-46Ml/d deficit could be met from small local schemes, but unlikely that it could be completely filled in this way. For present purposes, therefore, it is assumed that no further significant yield can be obtained locally by groundwater development or other small scale works.

The requirement of 46Ml/d could be met by:

- augmenting and raising Wimbleball reservoir;

- a further development in the Bristol Avon catchment near Bath;

- a combination of the two.

It was suggested in Section 5.1.2 that augmentation only of Wimbleball would probably yield of the order of 12Ml/d to WW, assuming the benefit is shared on the present basis. Augmentation and raising by 5m, on the other hand, would yield some 130Ml/d to SWWSL alone or, if shared, perhaps 70Ml/d to SWWSL and perhaps 40Ml/d to WW (these figures would need to be confirmed by further study). This falls short of the 46Ml/d sought.

Augmentation of Wimbleball and a 1.5m raising would yield about 104Ml/d to SWWSL alone, or perhaps 56Ml/d to SWWSL and perhaps 32Ml/d to WW (this would be adequate for the WW "low" forecast deficit).

Thus WW will need to look beyond Wimbleball within the planning horizon. As noted in Section 4.6, there is probably scope for yields in excess of this amount from the Avon at Bath, even after implementation of the Monks Wood scheme.

If WW do make partial use of Wimbleball, it would seem sensible to raise the reservoir by 1.5m. This would postpone the need for another development until about 2013. However, since

- use of Wimbleball by WW is less efficient in resource terms than its use by SWWSL;

- WW will anyway need to look elsewhere within the planning horizon,

it is logical that WW should relinquish any further claim they may have to Wimbleball, and pursue a more strategic scale of scheme on the River Avon at Bath. As the deficit without Wimbleball requires a new scheme to be in place by 2004, WW need to commence planning for such a scheme in the very near future.

Although such a strategy is entirely logical in resource planning terms, it must be clearly understood that foregoing their claim to further water from Wimbleball would impose a significant extra resource development cost upon WW. Estimates prepared in the mid 1980's (18,19) suggest capital costs to WW of the order of about £10m for further water from Wimbleball (pumped augmentation only), compared with £50m - £60m for a new development of Bath, albeit with a higher yield to the company.

If the 21Ml/d "low flow debit" is taken into account, WW would need a 67Ml/d scheme, in about 1998. In this case they would probably be compelled to make further use of Wimbleball, in order to gain sufficient time to promote an 'all new' scheme elsewhere.

5.3 Overview of Strategy

For the SWWSL supply area, two deficit scenarios have been examined:

- Scenario 1: likely demand forecasts, no cutbacks in outputs of existing sources due to environmental factors

- Scenario 2: likely demand forecasts adjusted for failure to achieve leakage targets, and available source outputs cut back by 36Ml/d to reflect environmental problems.

Under Scenario 1, the 2021 aggregate zonal deficit is estimated at about 159Ml/d, allowing a 5% planning margin on demand. This can be substantially met by:

- increased integration of strategic sub-zone sources;

- redevelopment of the Otter boreholes (7Ml/d);

- further development of River Exe system (7Ml/d);

- pumped augmentation of the three strategic reservoirs in the region (137Ml/d, subject to further study).

Under the above strategy, a 13Ml/d deficit may remain in 2021 between developed resources and peak period planning demand. This would arise principally in Roadford and Colliford zones. It could be met by an Axe based pumped storage scheme, or a smaller development nearer to the points of need. Since such a scheme would not be needed until towards the end of the planning period, a decision on its precise form does not yet need to be taken.

With the exception of pumped augmentation of Colliford and Roadford, all the above schemes have been evaluated to either pre-feasibility or full feasibility level. Assumptions have been made about the yield gain that can sensibly be achieved by augmenting the two reservoirs, and these need to be checked. This is particularly pressing in the case of Colliford (which would need to be augmented before Roadford) since the level of resource development in that catchment already appears relatively high (Table 3.2).

The only new storage developed under Scenario 1 would be to the Axe or Axe-equivalent scheme, with a capacity of, say, 2400Ml. This would increase the region's total water supply storage to 115,000Ml, equivalent to 5½ months' Scenario 1 annual average demand. This may be compared with the current figure of about 7½ months and the pre-Roadford figure of about 2 months.

Under Scenario 2, the 2021 deficit is estimated at 216Ml/d, allowing for a 5% planning margin on demand. This can be met by the above listed developments plus a major new reservoir scheme with a yield of about

100Ml/d, preferably in Devon or Cornwall. Such a scheme would not be needed until about 2014; a number of options may be deduced from previous resources studies in the South-West. It would be in the NRA's interest to review these in the light of changes which have occurred over the last 20 years or so, and draw up a revised short-list of schemes.

The extra capacity of perhaps 15,000Ml which such a scheme would bring would afford some six months' of storage at Scenario 2 average annual demand.

Alternatively, the size of such a scheme could be reduced to about 26Ml/d if metering were to be introduced throughout the region. Present analysis suggests that this is not economically attractive whilst significant undeveloped water resources remain available locally; however, this position may change and therefore needs to be kept under review.

Under Scenario 2, pumped augmentation of Colliford and Roadford is needed sooner (1999 and 2005 and respectively), and comments above about the need to study these schemes are emphasised.

The foregoing discussion assumes that Wessex Water's use of Wimbleball continues as at present, but that they receive no share of the extra yield occurring from further development of the reservoir.

It is shown that WW have a clear need for a significant new scheme within the planning horizon, and that their needs could not be fully met even with a full share of an augmented Wimbleball raised by 5m. Their use of Wimbleball for direct supply is inefficient in resource terms, and it is suggested instead that WW be encouraged to forego any rights they may have to move water from the reservoir, and to opt instead for a strategic development on the River Avon near Bath. In the longer term, large quantities of additional water are more assured to WW from the Severn system than from the Exe, and a further development at Bath would help to re-align their distribution system to receive supplies from the North of their supply area.

It is acknowledged that this recommendation has significant adverse cost implications for WW.

It is perhaps worth noting that the benefits of strategic planning in resource allocation and optimisation terms are plainer to the NRA than to the water companies. The latter have also to take into consideration the funding of major capital works, operational factors etc; this can lead to a preference to develop resources in small parcels, and deferment of major new schemes for as long as possible, unless they can be phased. Small schemes will continue to play an important part in water resource development, but those that might compromise the resource yield obtainable from a river system if developed in a more strategic manner should be discouraged.

TABLE 5.1 SWWSL SUPPLY AREA: SCENARIO 1 PROJECTED PEAK 4-WEEK PWS DEFICITS

RESOURCES/ YEAR	FORECAST SURPLUS/DEFICIT +/- (Ml/d)			
	Colliford	Roadford	Wimbleball	Overall
		N & SW Devon & Plymouth	Allers & Pynes & E Devon	
Available Resources	204	332	110	646
1991	24	39	1	69
1996	35	50	2	92
2001	18	28	-5	47
2006	0	6	-13	-1
2011	-18	-16	-21	-49
2016	-37	-39	-30	-99
2021	-57	-63	-39	-152

TABLE 5.2 SWWSL SUPPLY AREA: SCENARIO 2 PROJECTED PEAK 4-WEEK PWS DEFICITS

RESOURCES/ YEAR	FORECAST SURPLUS/DEFICIT +/- (Ml/d)			
	Colliford	Roadford	Wimbleball	Overall
		N & SW Devon & Plymouth	Allers & Pynes & E Devon	
Available Resources	189	314	107	610
1991	9	21	-2	33
1996	10	26	-3	45
2001	-8	2	-4	-5
2006	-27	-21	-11	-54
2011	-47	-44	-19	-103
2016	-67	-68	-28	-155
2021	-88	-92	-36	-208

TABLE 5.3 WIMBLEBALL ZONE DEVELOPMENT OPTIONS

Reference	Proposed	Key Features	Effect on 4-week Peak DRY (Ml/d)		Remarks
(a)	Thorverton (Exe) prescribed flow (pf) reduction	Reduce pf from current 273Ml/d to 163Ml/d ($=Q_{95}$).	+11		Effects on estuary and existing protected rights not yet studied. May be feasible, subject to adequate investigations.
(b)	Otter boreholes	Overcome poor performance of existing wellfields by drilling new boreholes in more appropriate locations	+7		Studied for SWWSL by MRM Partnership. Has been modelled but field investigations needed to confirm. Would increase DRY from 25 to 32Ml/d, compared with licensed entitlement of 36Ml/d, and could reduce impact on river flows. Therefore promotion should be straightforward.
(c)	Pumped augmentation of Wimbleball lake from Exebridge	Increases lake inflow and thus allows larger draught upon it. Increased reservoir releases to support higher abstraction entitlements at Bolham and North Bridge.	+44 +39 +37	with (a) and (d)/(e) if Taw transfer discontinued with (a) and (d)/(e) but with Taw transfer with (a) and (d)/(e) and increased WW take but without Taw transfer	EA and feasibility study results promising, though adverse impacts on lake-based leisure. Intake capacity can be phased by installing some pumpsets later. Yields based on 28.3Ml/d take by Wessex Water, compared with 31.8Ml/d existing entitlement. For present purposes, a reduction of 7Ml/d in estimated yields to SWWSL is suggested to allow WW to take their full present entitlement. WW may also want a share of augmentation gain, as they have a joint interest in the reservoir.

TABLE 5.3 (Cont'd)

Reference	Proposed	Key Features	Effect on 4-week Peak DRY (Ml/d)	Remarks
(d)	Creedy abstraction	New intake on R Creedy and extend Pynes TW	+7 ((a) + (d) combined yield = 16))	Reduces flows to Exe estuary.
(e)	Culm abstraction	New intake on R Culm and extend Pynes TW	+7 ((a) + (e) combined yield = 16))	WQ problems. Reduces flow to estuary.
(f)	Axe pumped storage	New reservoir at Higher Bruckland, filled by pumping from R Axe at Whitford Bridge	+22	Studied in detail for SWWSL by MRM Partnership
(g)	Raise Wimbleball dam	Increase dam height by 1.5 or 5m, significantly enlarging storage	+67 (1.5m raising) +93 (5m raising) Both with c in place	Original design allows for 1.5m raising, but no environmental assessment done and significant (temporary) landscape impact likely

TABLE 5.4 WW SOMERSET/AVON SUPPLY AREA: PROJECTED PWS PEAK PERIOD DEFICITS (Ml/d)

Year	Available Resources	Likely Demand	Surplus/Deficit +/-
1991	312	278	34
1996	343	299	44
2001	343	320	23
2006	343	332	11
2011	343	344	-1
2016	343	357	-14
2021	343	370	-27

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

(a) Both South West Water and Wessex Water forecast public water demand in an equitable and broadly comparable manner.

(b) Over the planning horizon of 1991-2021, public water demand is set to grow by about 1% per year on average in each region.

(c) SWWSL plan to reduce significantly the current levels of unaccounted for water in their supply area.

(d) In some of their supply zones, SWWSL targets for ufw may be judged as optimistic when compared with reasonable expectations as set out in published literature on the subject.

(e) Of the determinands varied to check sensitivity of demand forecasts, choice of factors used to generate peak period demands have the most critical impact on these values. These factors should exhibit a downward trend as supply systems become better integrated. In the SWWSL area, peak demands occur early in the year, before drought impacts are fully established.

(f) In the SWWSL supply area, Colliford zone has the highest predicted demand growth, and East Devon the lowest.

(g) It is not possible to forecast private demand with confidence. However, projections suggest that it should be possible to respond to most forms of consumptive use demand growth within the normal framework of abstraction licence determination. The exception to this is spray irrigation, particularly in the Exe/Clyst/Otter valleys and West Cornwall. Here particular caution is needed, and it may be only possible to permit new abstractions in the winter months, in which case they would need to have associated storage. Alternatively, a part of the enhanced yield from an up-rated Wimbleball system could be dedicated to supporting irrigation abstractions, along the lines of the "water-bank" principle. However, this would benefit irrigators only on the main River Exe.

(h) Resource yield information has been provided by SWWSL, but full verification has not been possible. However, quoted source outputs compare with the 1989 experience, when many schemes were operated close to their limits, and with data from external consultants' reports on various specific potential developments.

(i) Although considerable progress has been made in integrating water supply sources in the course of the Roadford and Colliford schemes, further scope remains. In the short term, links need to be improved between the Exe system and East Devon, and in the medium term, the ability to move water easily between the three strategic reservoir zones will be necessary. This will further increase operational flexibility to respond to events such as pollution incidents, system failure and local demand peaks.

(j) There remains considerable scope to develop further resources in the South West, and, at current prices, this represents a more economic response to demand growth than universal metering.

(k) On the basis of investigating two alternative future deficit scenarios, it seems likely that much can be achieved through further integration of sources, redevelopment of the Otter valley wellfields and modifications to existing schemes in the Exe valley, including pumped augmentation of Wimbleball. Pumped augmentation of Roadford and Colliford would also be needed.

(l) This assumes that the Taw transfer is discontinued. The transfer has been shown elsewhere (10) to be less efficient in resource terms than alternative developments on the Exe system.

(m) In the lower deficit scenario, a further increase in yield of at least 13 Ml/d would also be needed within the planning horizon. An Axe pumped storage scheme, or similar sized development elsewhere, might be appropriate. In the higher deficit scenario, a new scheme with a yield approaching 100 Ml/d would be required.

In the latter case, the deficits arise principally in the Colliford/Roadford zones, and it is suggested that a strategic scheme in South or West Devon would be appropriate. However, under both scenarios, the "all-new" scheme is over 20 years away, giving time for early long term planning and assessment of options, and for upgrading of the supply network.

(n) In resource terms, the needs of Wessex Water are better met entirely from within their own region. This is considered preferable to partial use of an enhanced Wimbleball with some input from the R. Avon. However, the former solution would be much more costly for WW.

(o) The strategy presumes certain yield gains from pumped augmentation of Colliford and Roadford that have yet to be verified, but are considered reasonable on current evidence.

(p) The strategy encompasses a reasonable level of reservoir provision for public supply in the South West, in terms of the period for which average demand could be met entirely from storage.

6.2 Recommendations

(a) The NRA should encourage SWWSL to respond to the pressing supply problems in East Devon by means of improved integration with Allers and Pynes, and redevelopment of the Otter valley wellfields.

(b) In terms of efficient development of water resources, the next scheme should be pumped augmentation of Wimbleball followed by improved links between the lower Exe and South West Devon. The implications for SWWSL of augmenting Wimbleball in the near future, as an alternative to development of an Axe pumped storage scheme as the first step, needs to be further investigated.

(c) Improved integration between Roadford and Colliford zones should also be encouraged.

(d) The yield gain to be derived and from pumped augmentation of Colliford and Roadford needs to be established at an early date.

(e) Long term planning should be initiated, with a lead-in time of 20 years, for location and assessment of the next generation of regional strategic reservoir storage and distribution network improvements.

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FIGURES

HALCROW

SWWSL SUPPLY AREA PREDICTED POPULATION

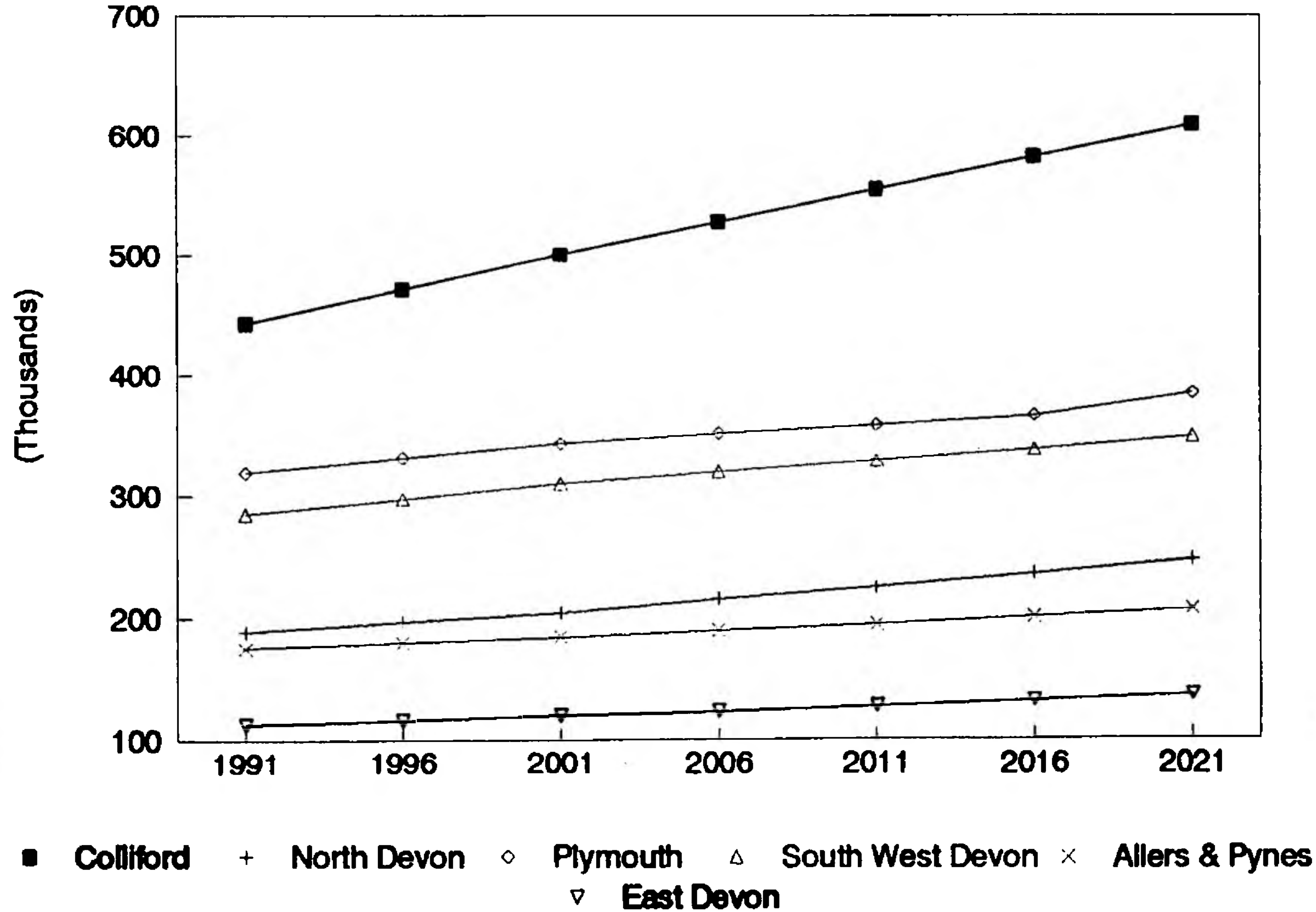


Figure 1

COLLIFORD ZONE DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996

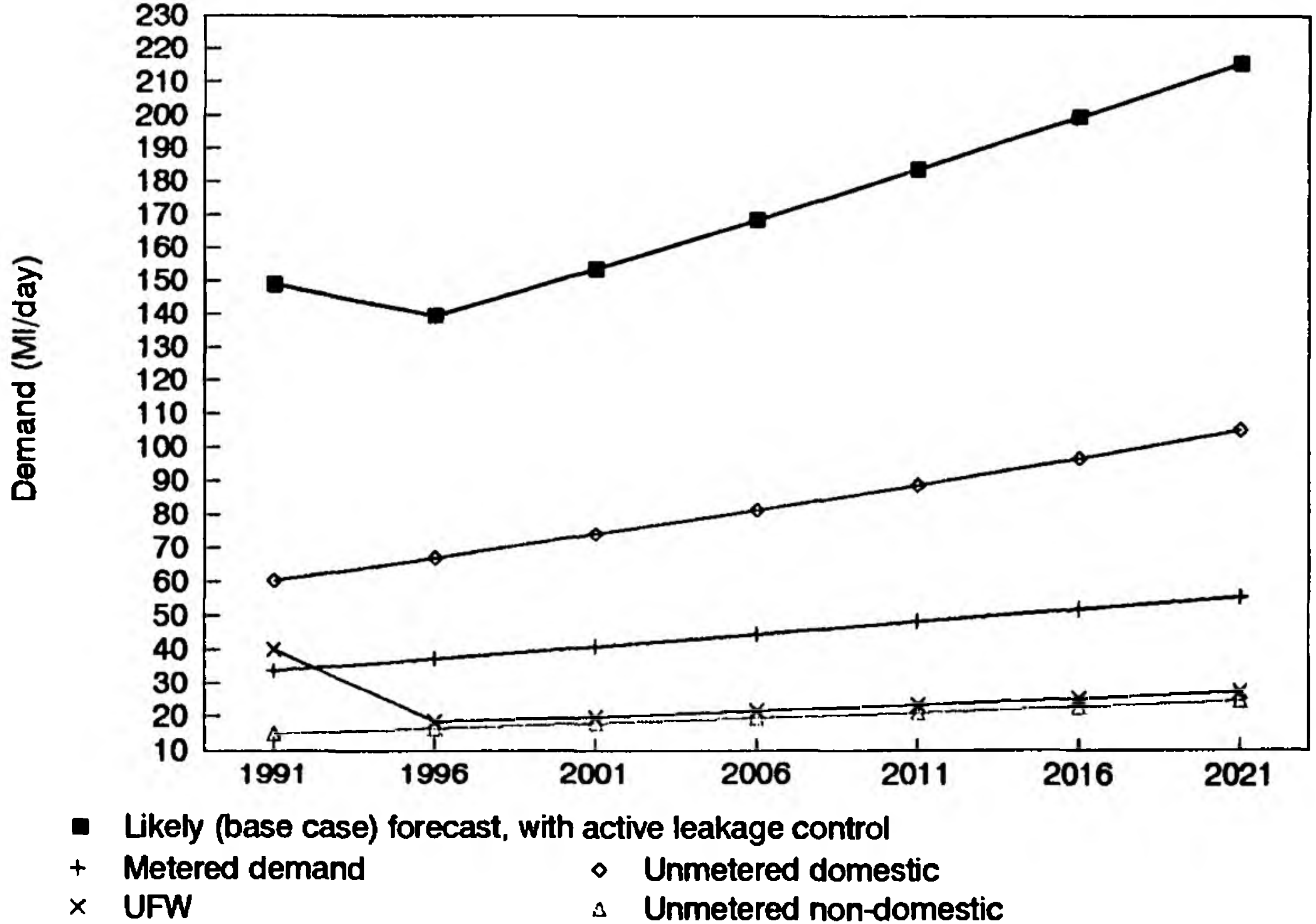


Figure 2a

NORTH DEVON ZONE DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996

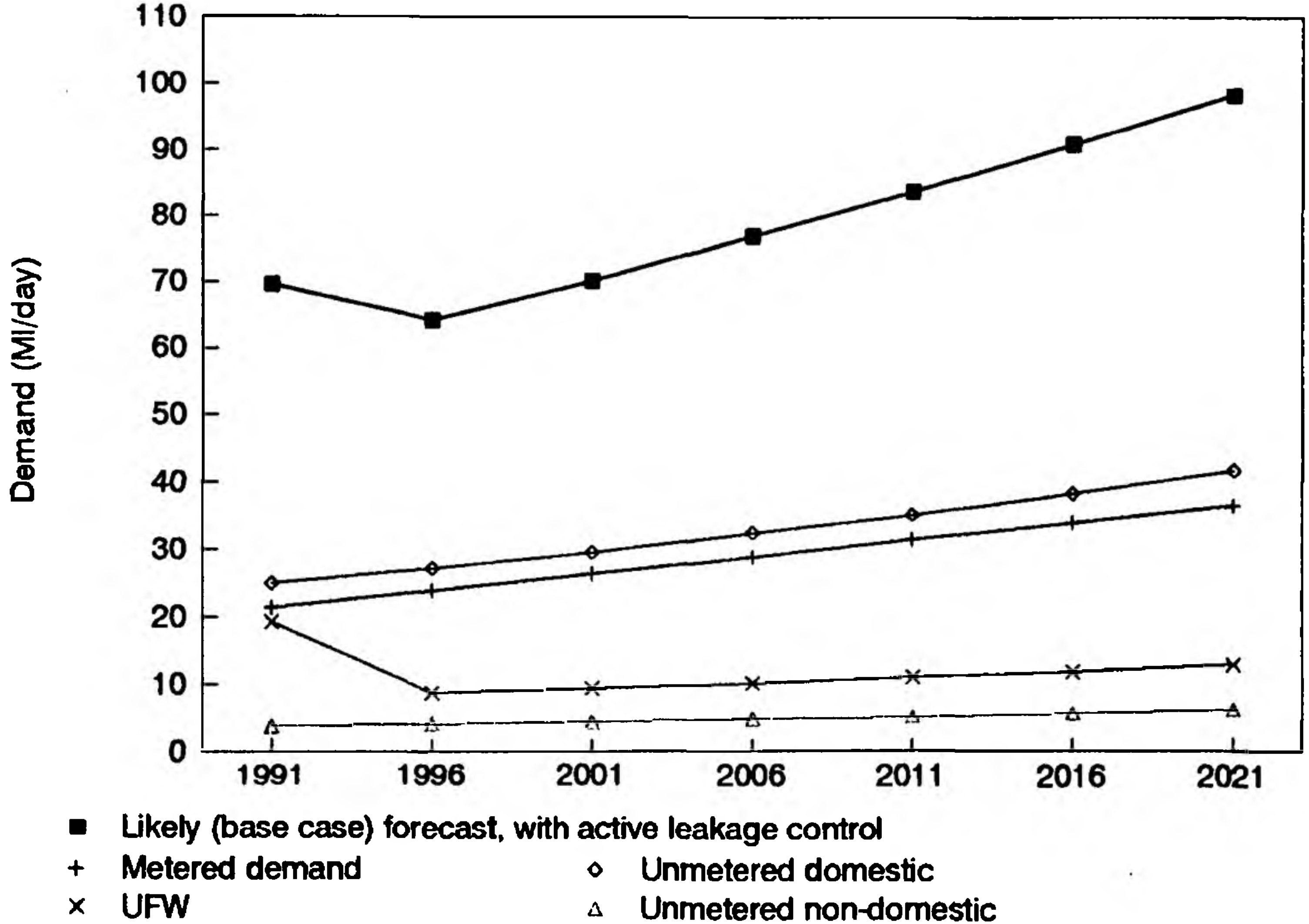
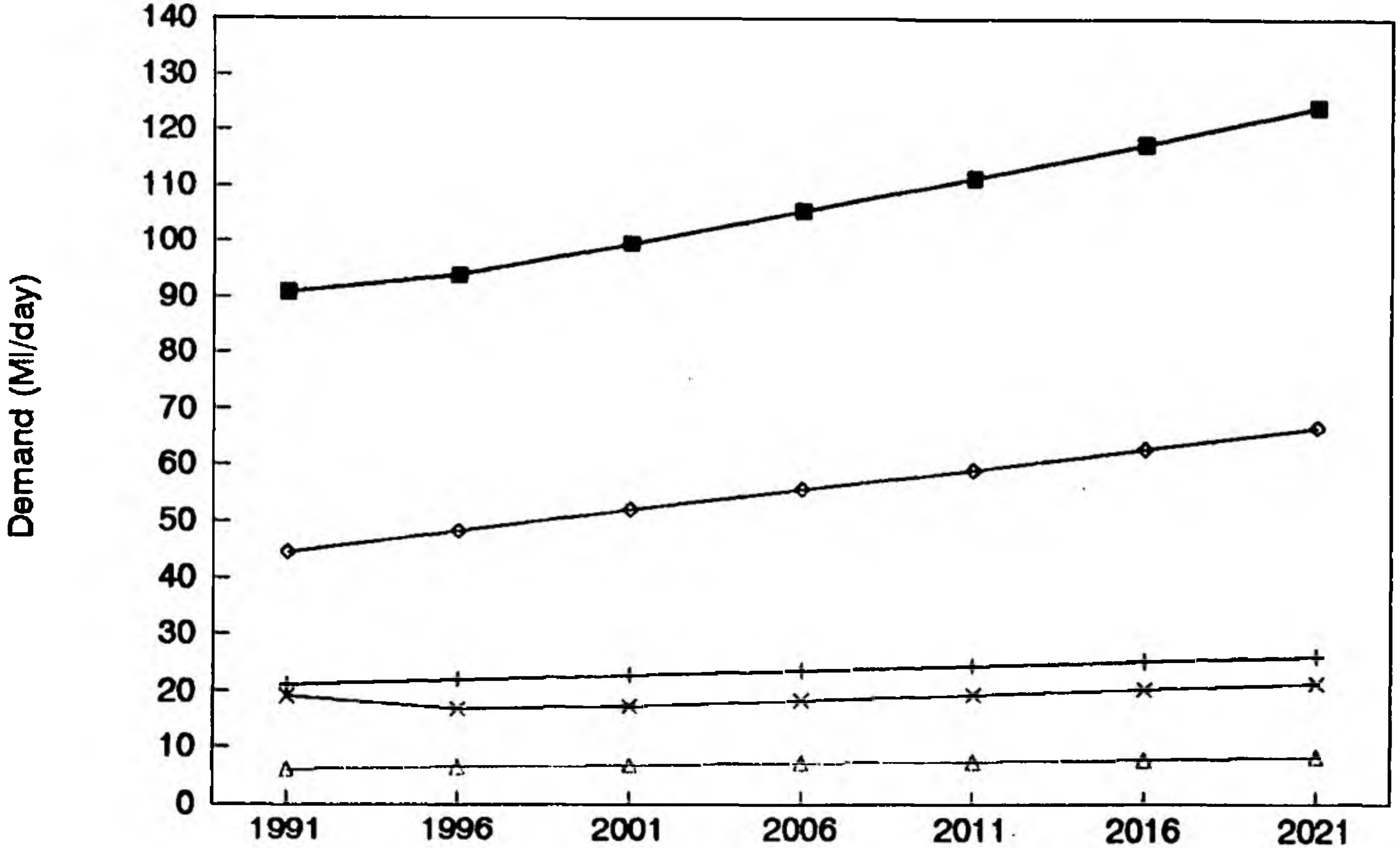


Figure 2b

PLYMOUTH ZONE DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996



■ Likely (base case) forecast, with active leakage control

\+ Metered demand

◇ Unmetered domestic

× UFW

△ Unmetered non-domestic

Figure 2c

SOUTH-WEST DEVON ZONE DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996

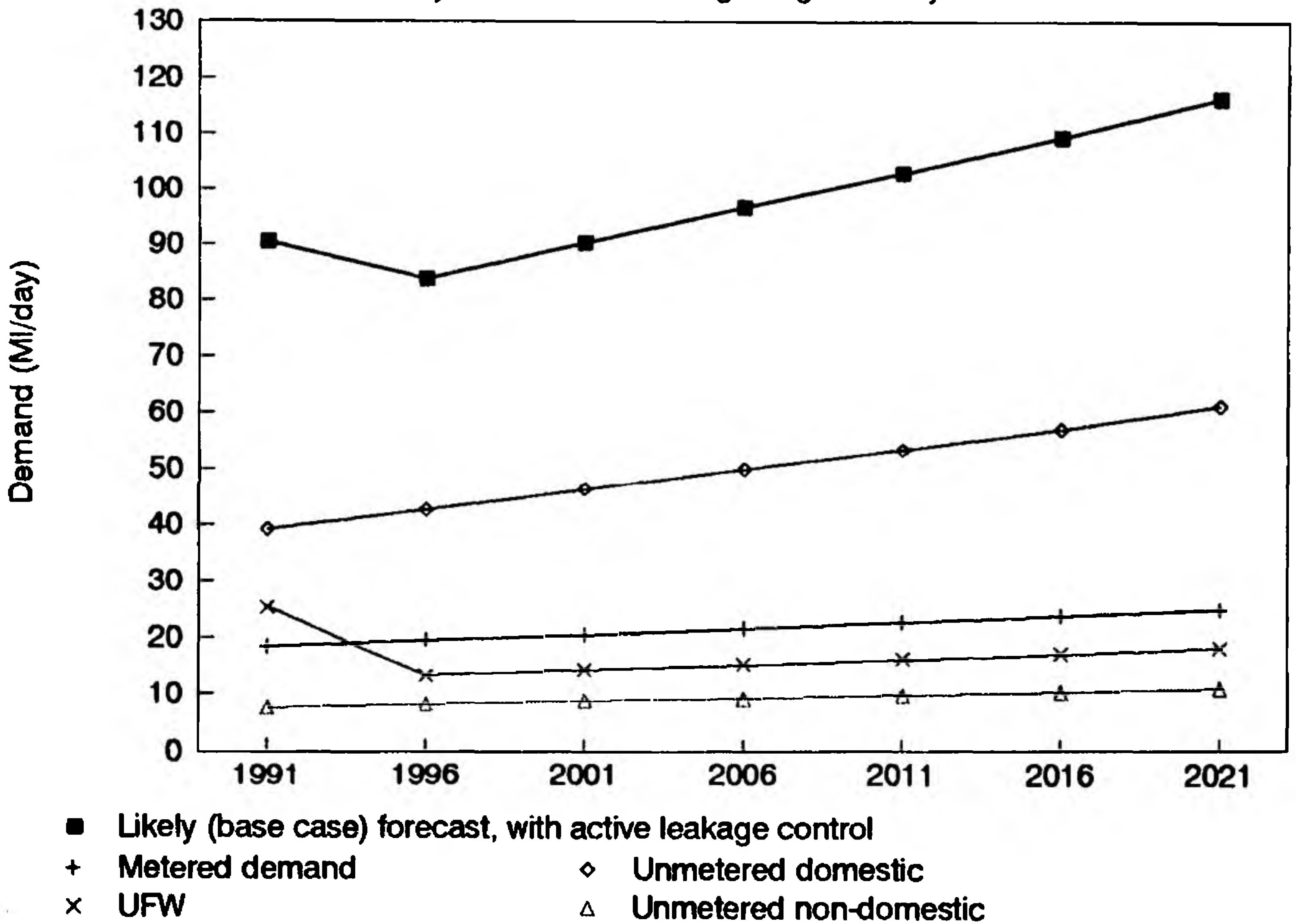


Figure 2d

ALLERS & PYNES ZONE DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996

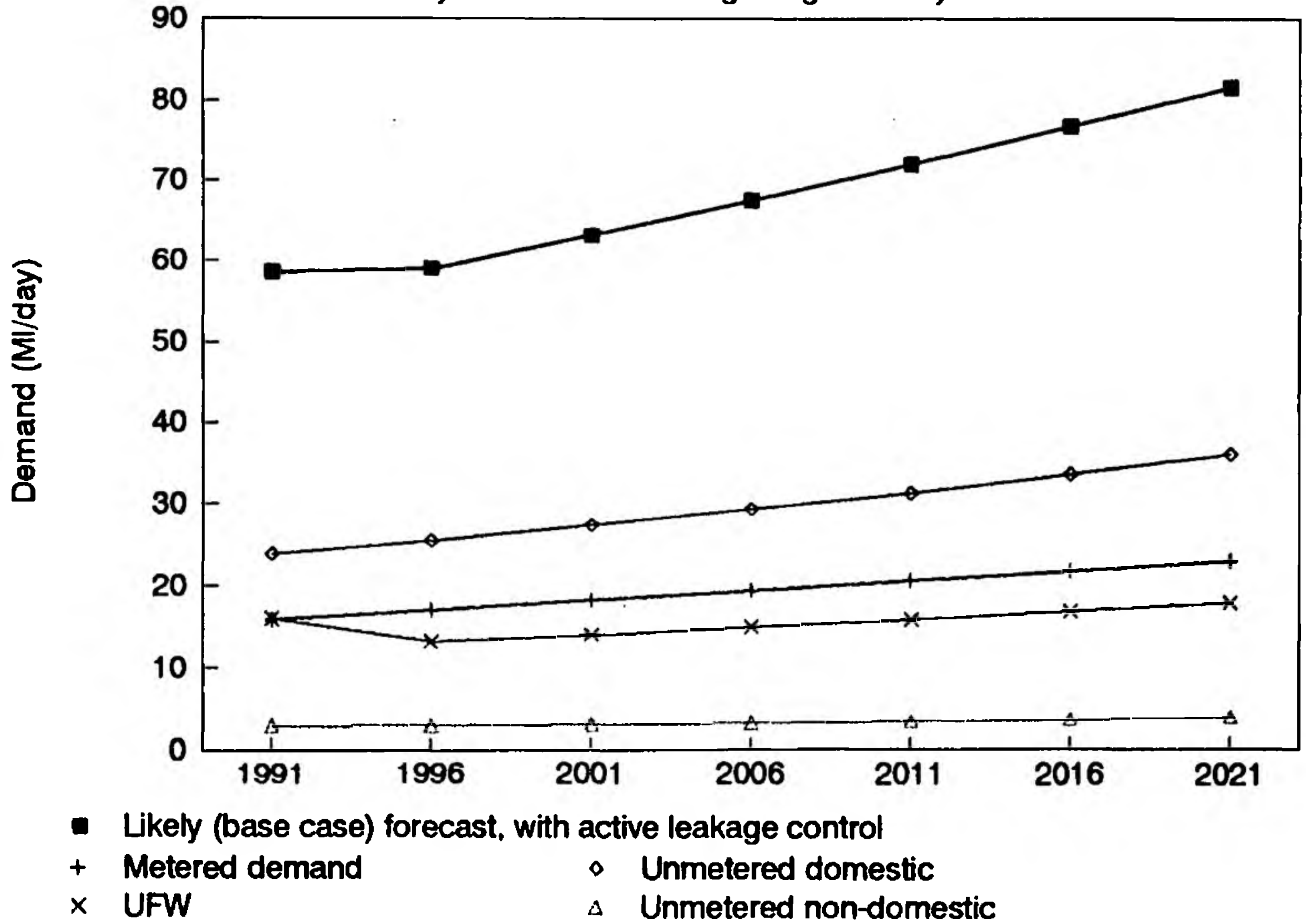


Figure 2e

EAST DEVON ZONE DEMAND BY COMPONENT

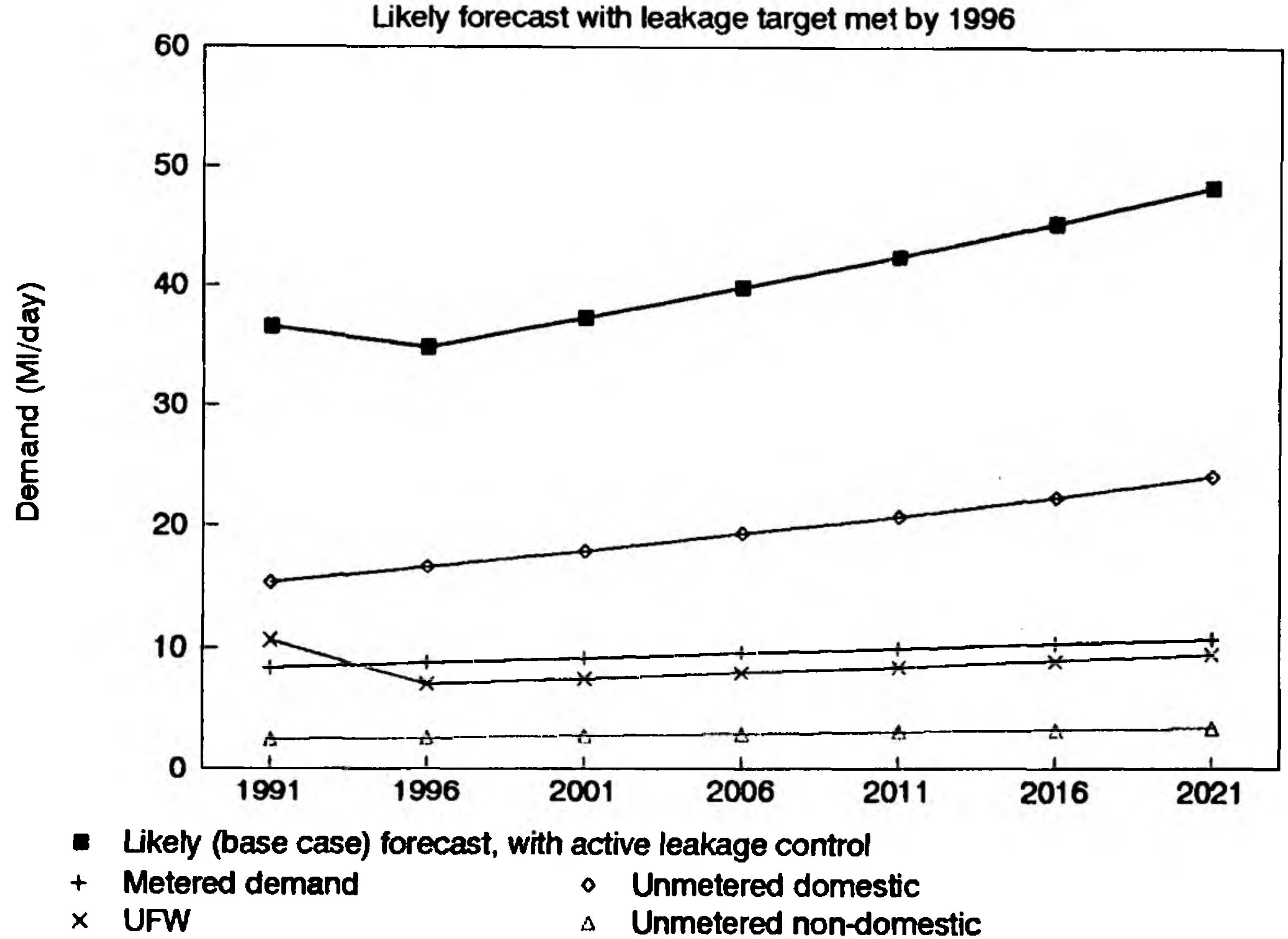


Figure 2f

SOUTH-WEST REGION DEMAND BY COMPONENT

Likely forecast with leakage target met by 1996

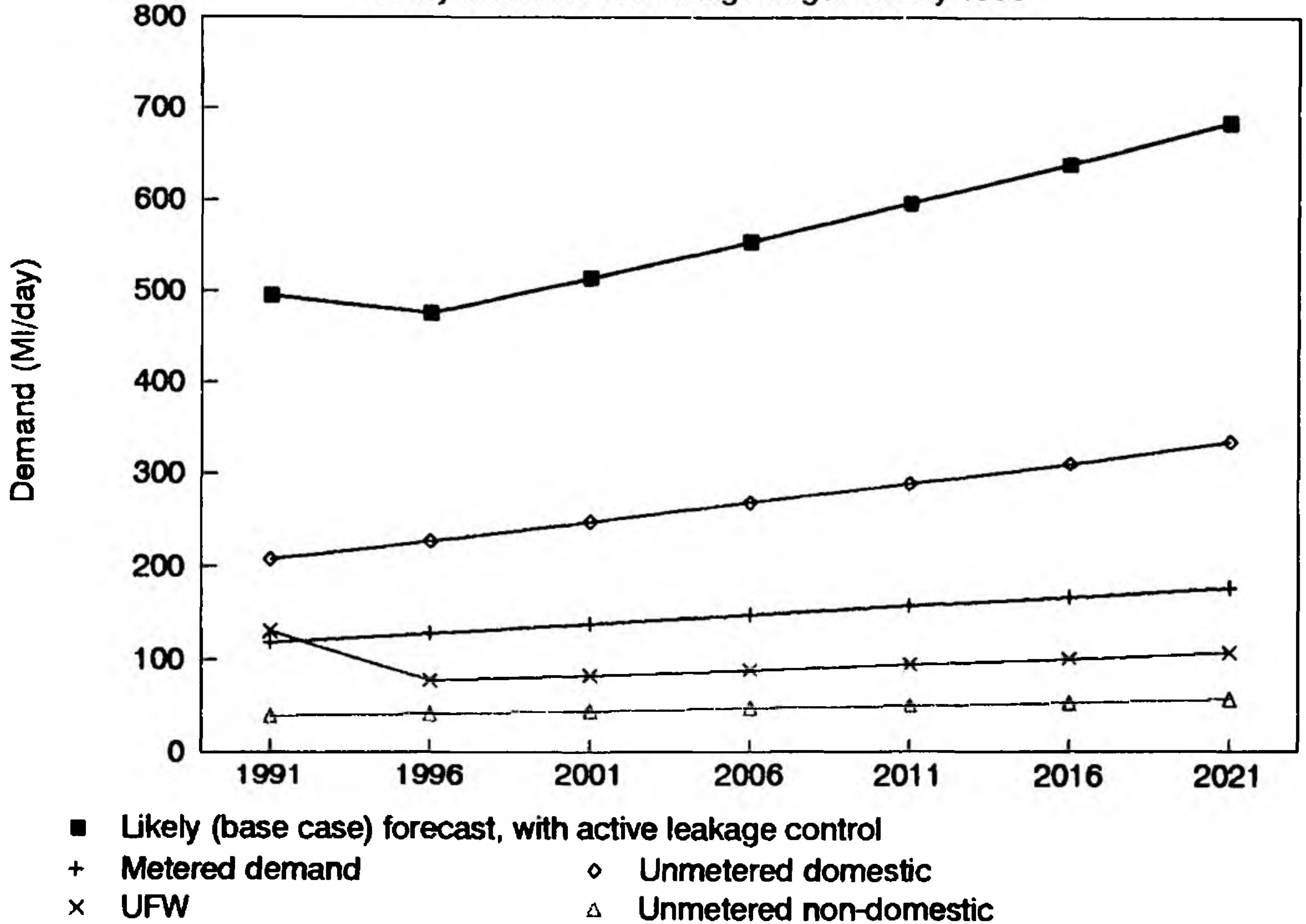
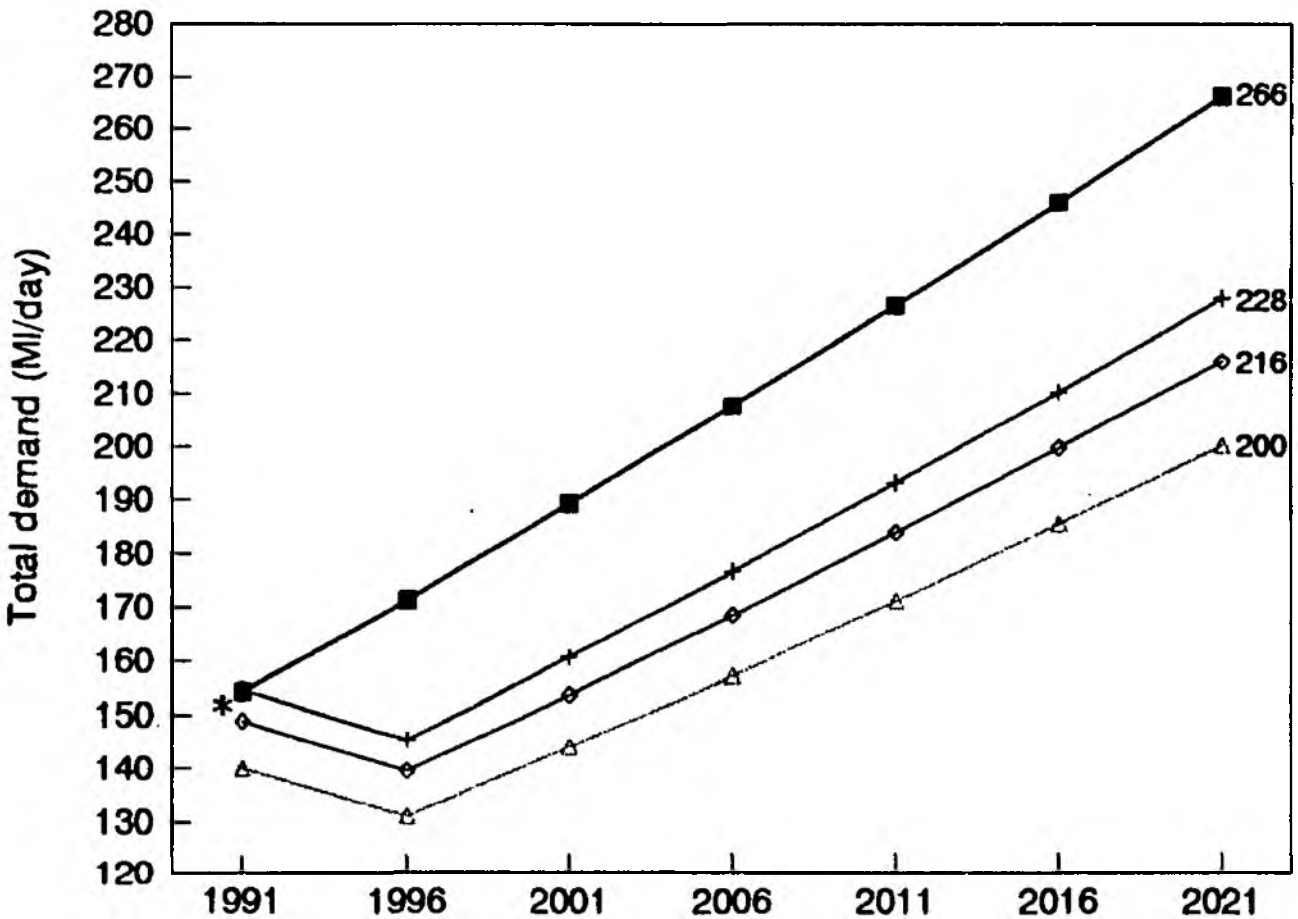


Figure 2g

COLLIFORD ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



Δ Low forecast, with active leakage control

+ High forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

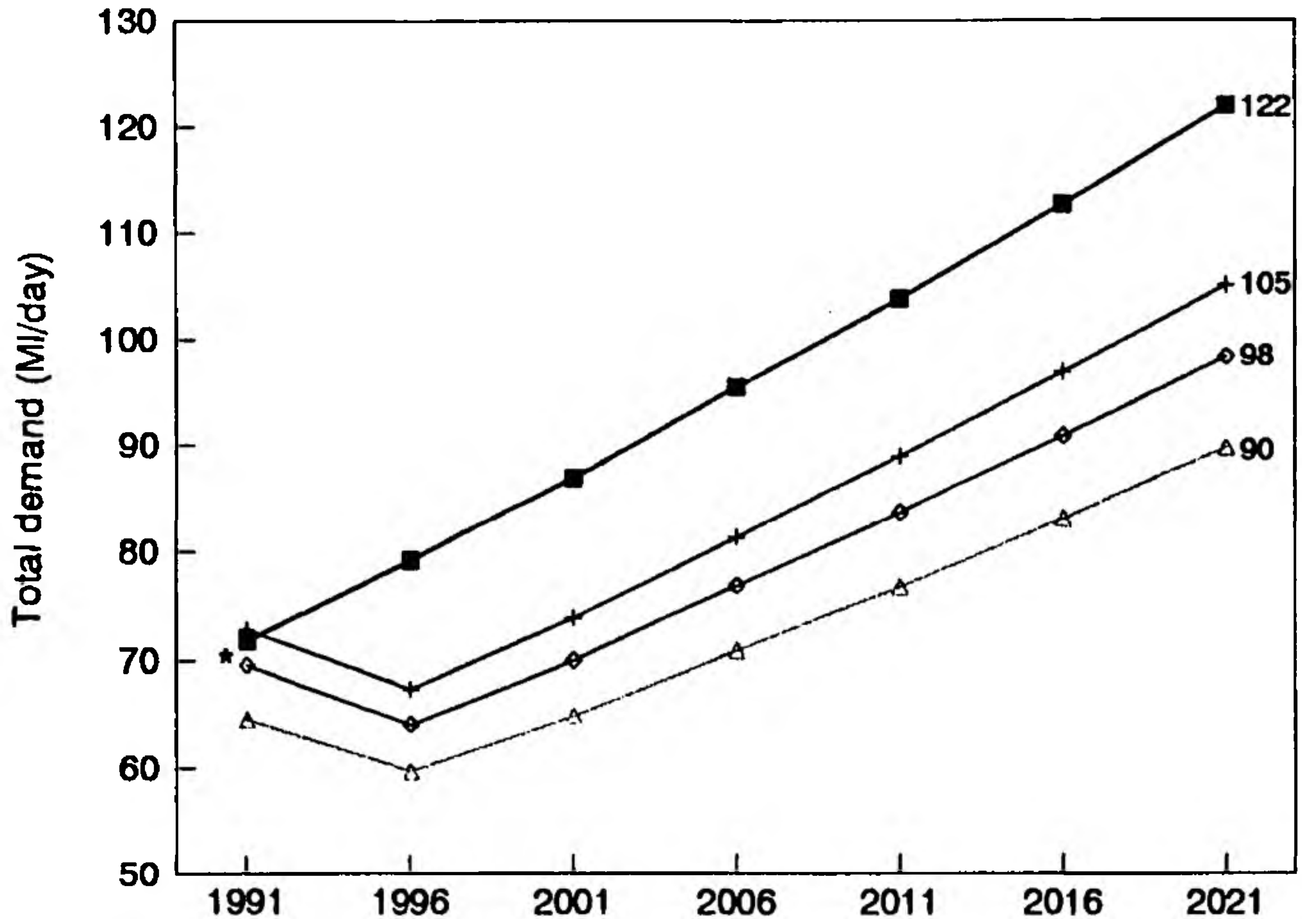
■ Likely forecast, without active leakage control

* Non-coincidence of likely forecasts in 1991, as figures are projected from 1990

Figure 3a

NORTH DEVON ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

+ High forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

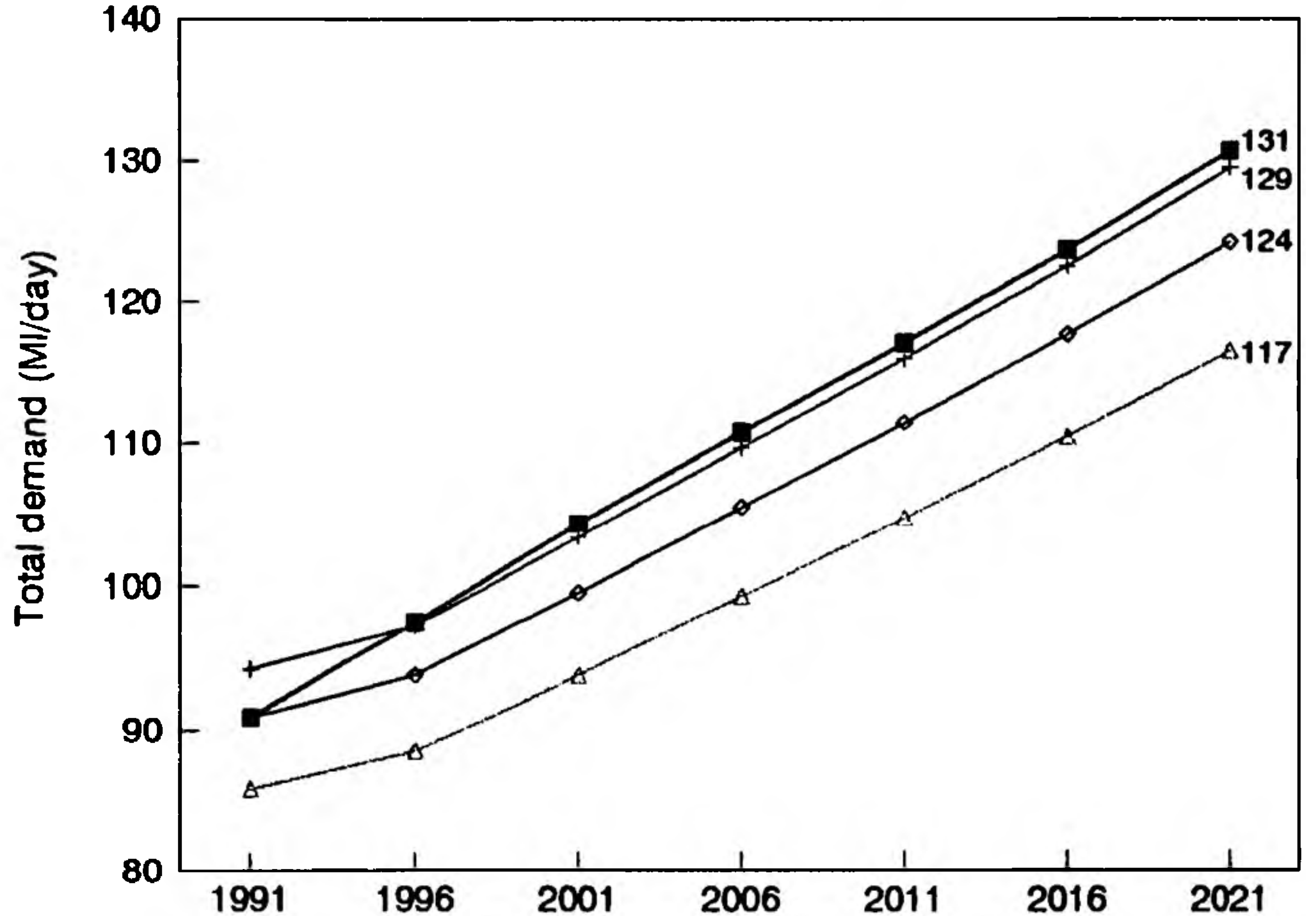
■ Likely forecast, without active leakage control

* Non-coincidence of likely forecasts in 1991, as figures are projected from 1990

Figure 3b

PLYMOUTH ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

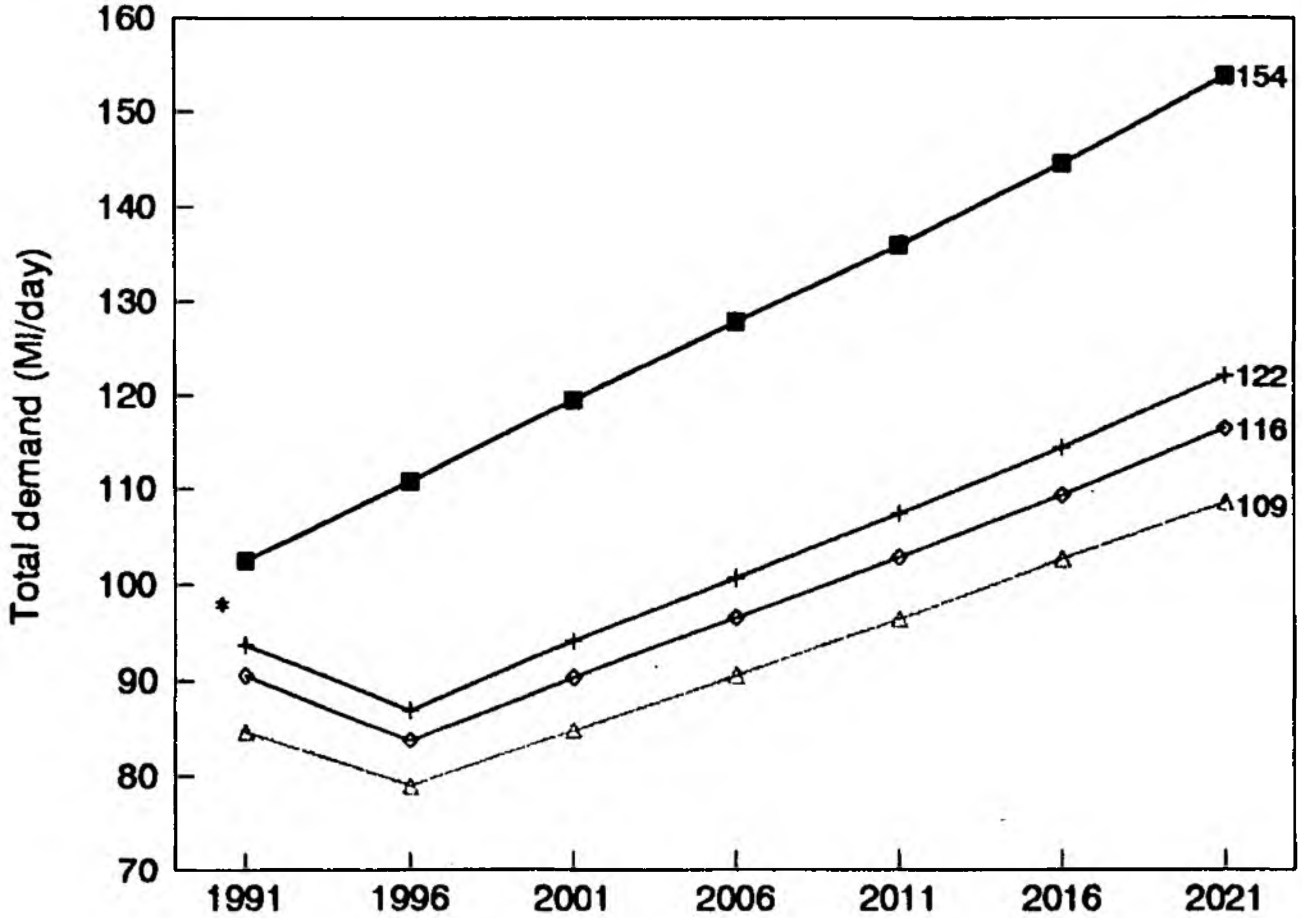
+ High forecast, with active leakage control

■ Likely forecast, without active leakage control

Figure 3c

SOUTH-WEST DEVON ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

+ High forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

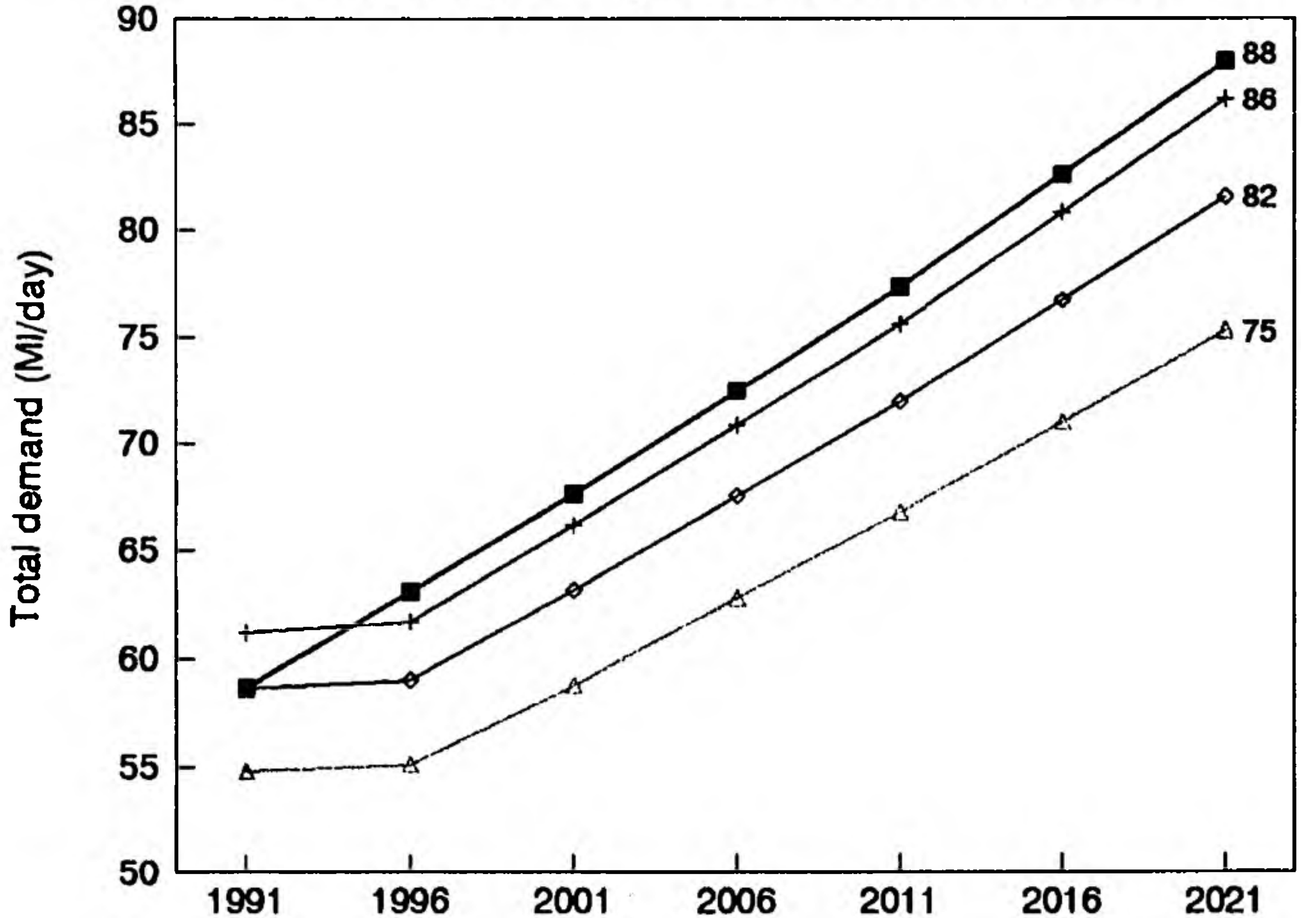
■ Likely forecast, without active leakage control

* Non-coincidence of likely forecasts in 1991, as figures are projected from 1990

Figure 3d

ALLERS & PYNES ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

+ High forecast, with active leakage control

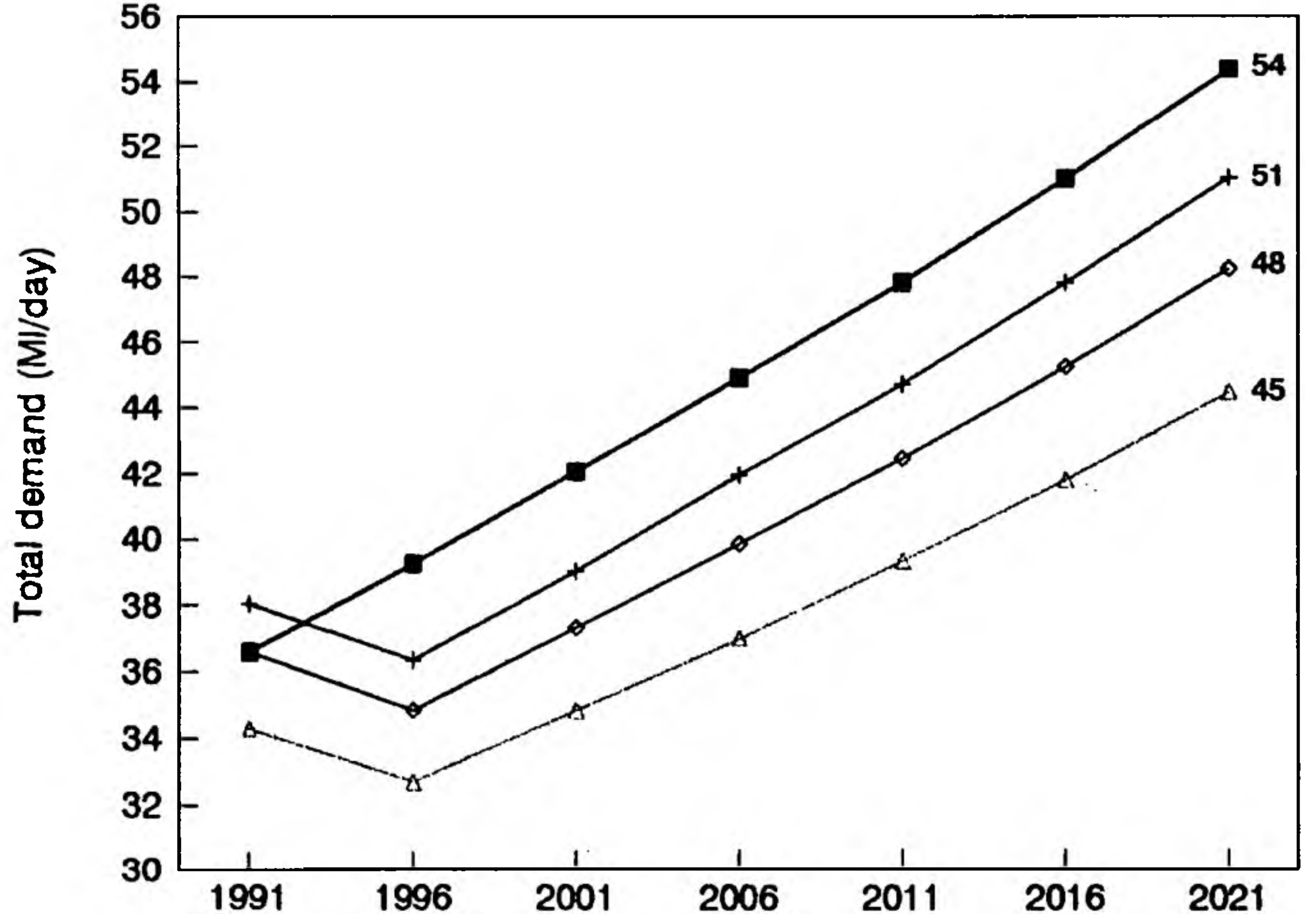
◇ Likely (base case) forecast, with active leakage control

■ Likely forecast, without active leakage control

Figure 3e

EAST DEVON ZONE DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

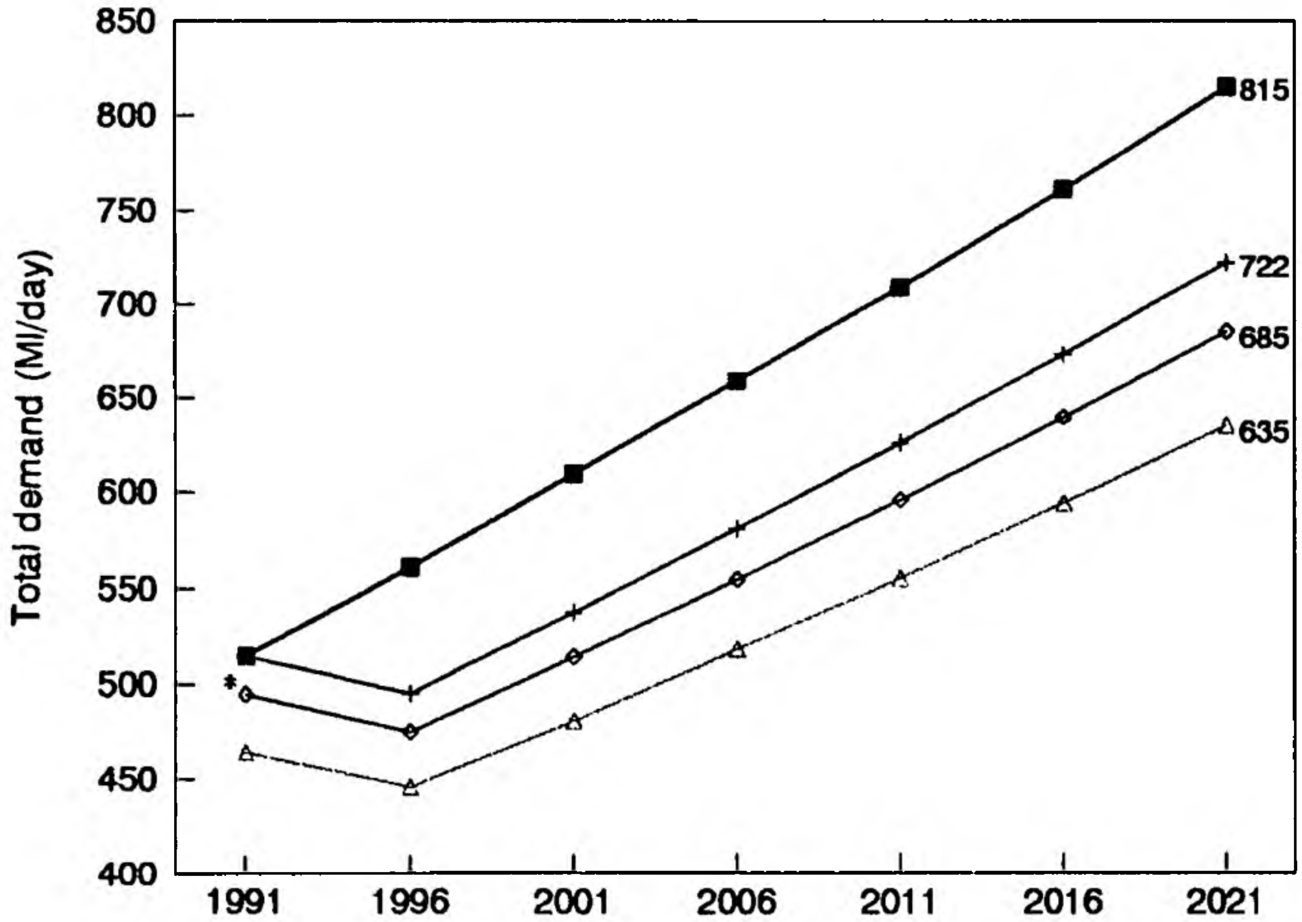
\+ High forecast, with active leakage control

■ Likely forecast, without active leakage control

Figure 3f

SOUTH-WEST REGION DEMAND FORECASTS

Leakage target met by 1996 / No active leakage control



△ Low forecast, with active leakage control

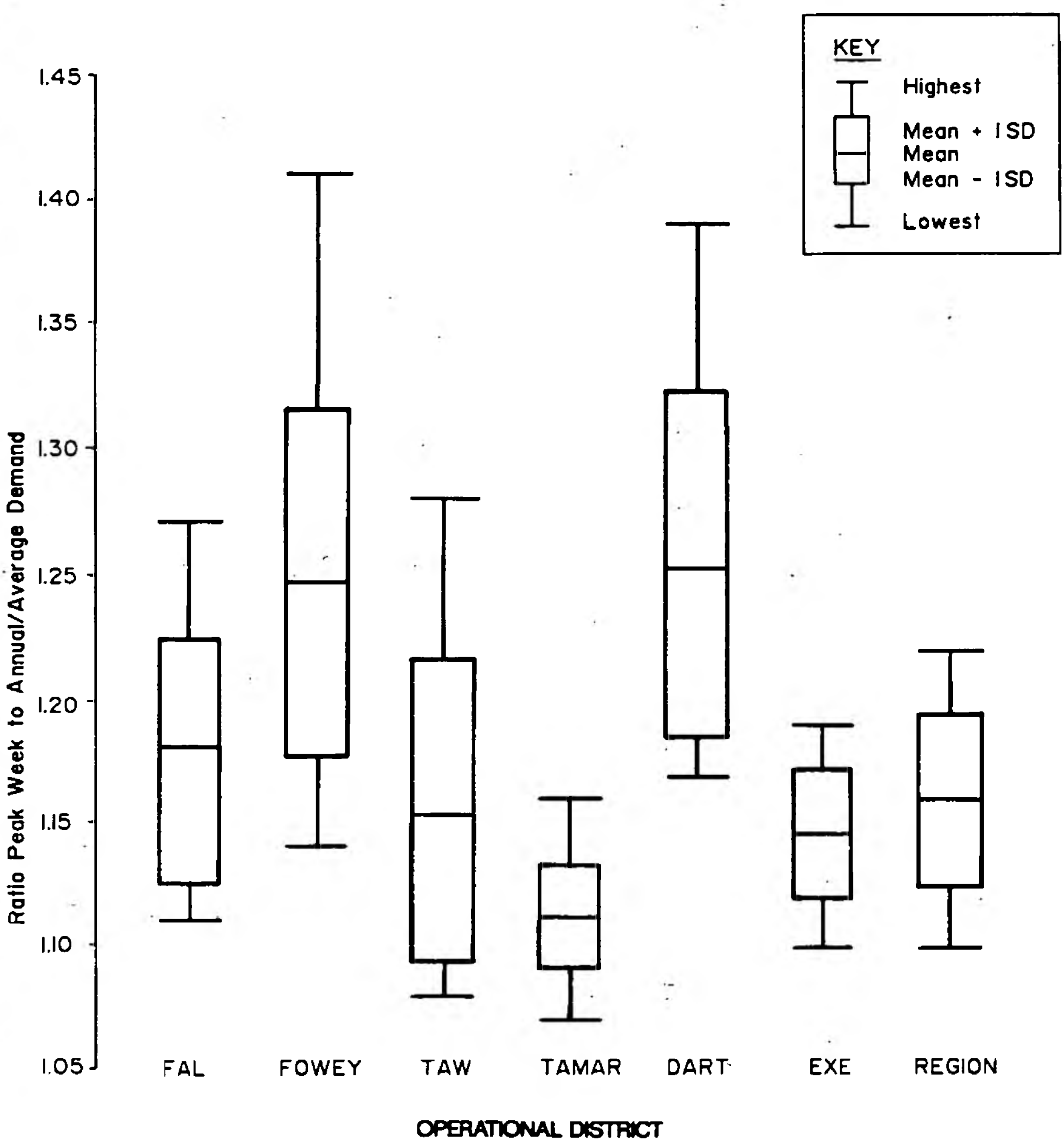
+ High forecast, with active leakage control

◇ Likely (base case) forecast, with active leakage control

■ Likely forecast, without active leakage control

* Non-coincidence of likely forecasts in 1991, as figures are projected from 1990

Figure 3g



VARIATION IN OPERATIONAL DISTRICT
DEMAND PEAK WEEK FACTORS
DURING THE YEARS 1976 -1990

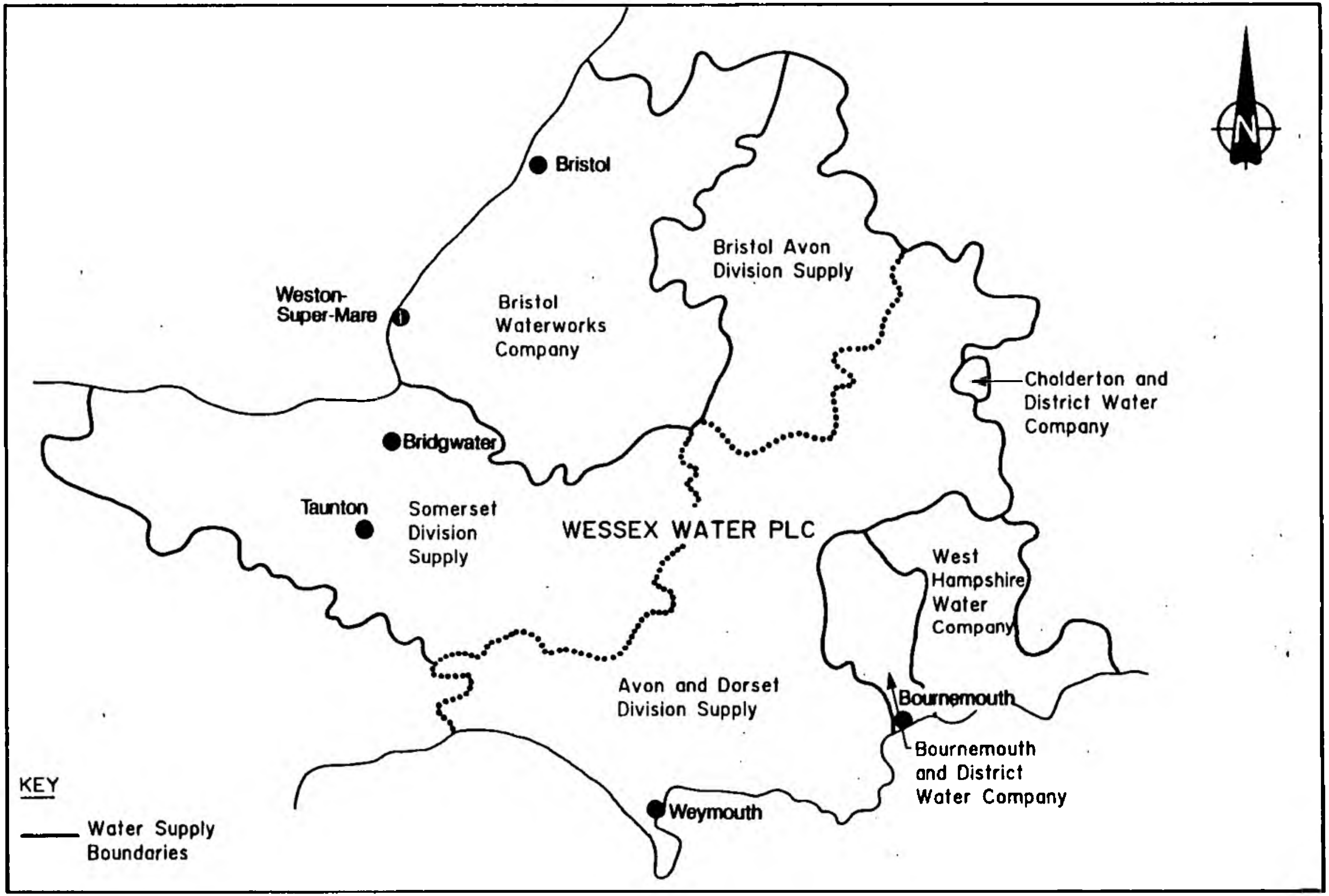


Figure 5

WESSEX REGION
WATER SUPPLY BOUNDARIES

SOMERSET AND AVON ZONE DEMAND FORECASTS

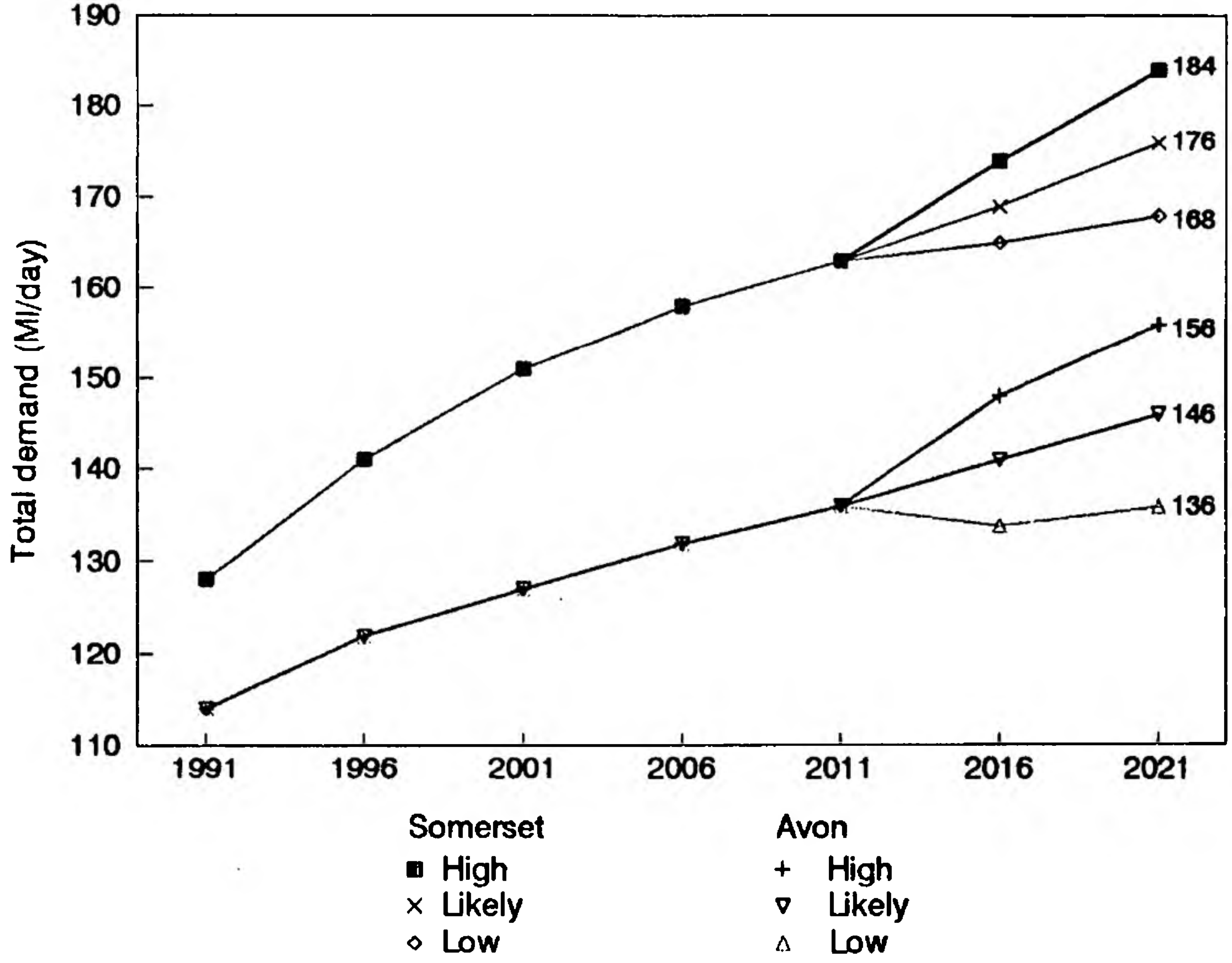
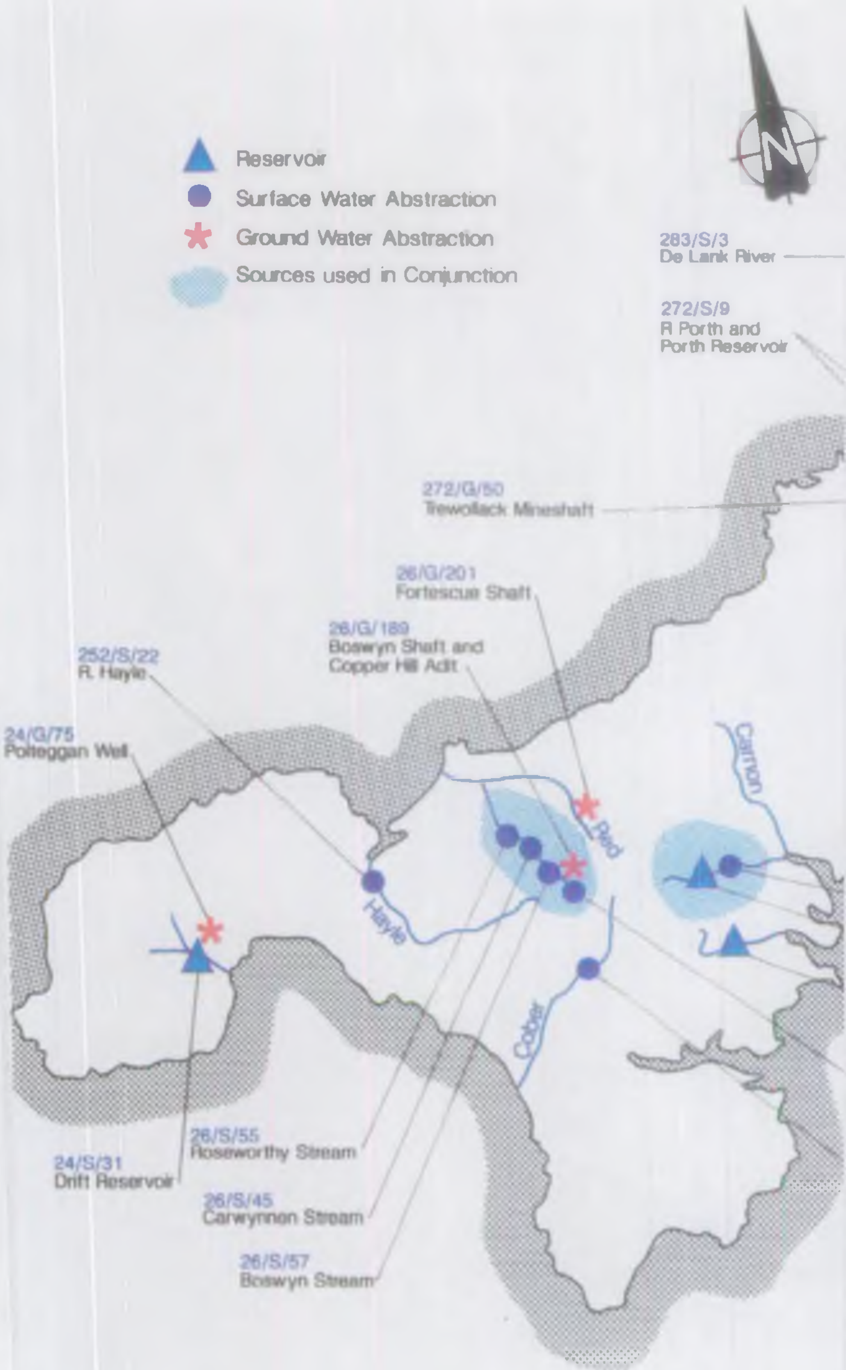
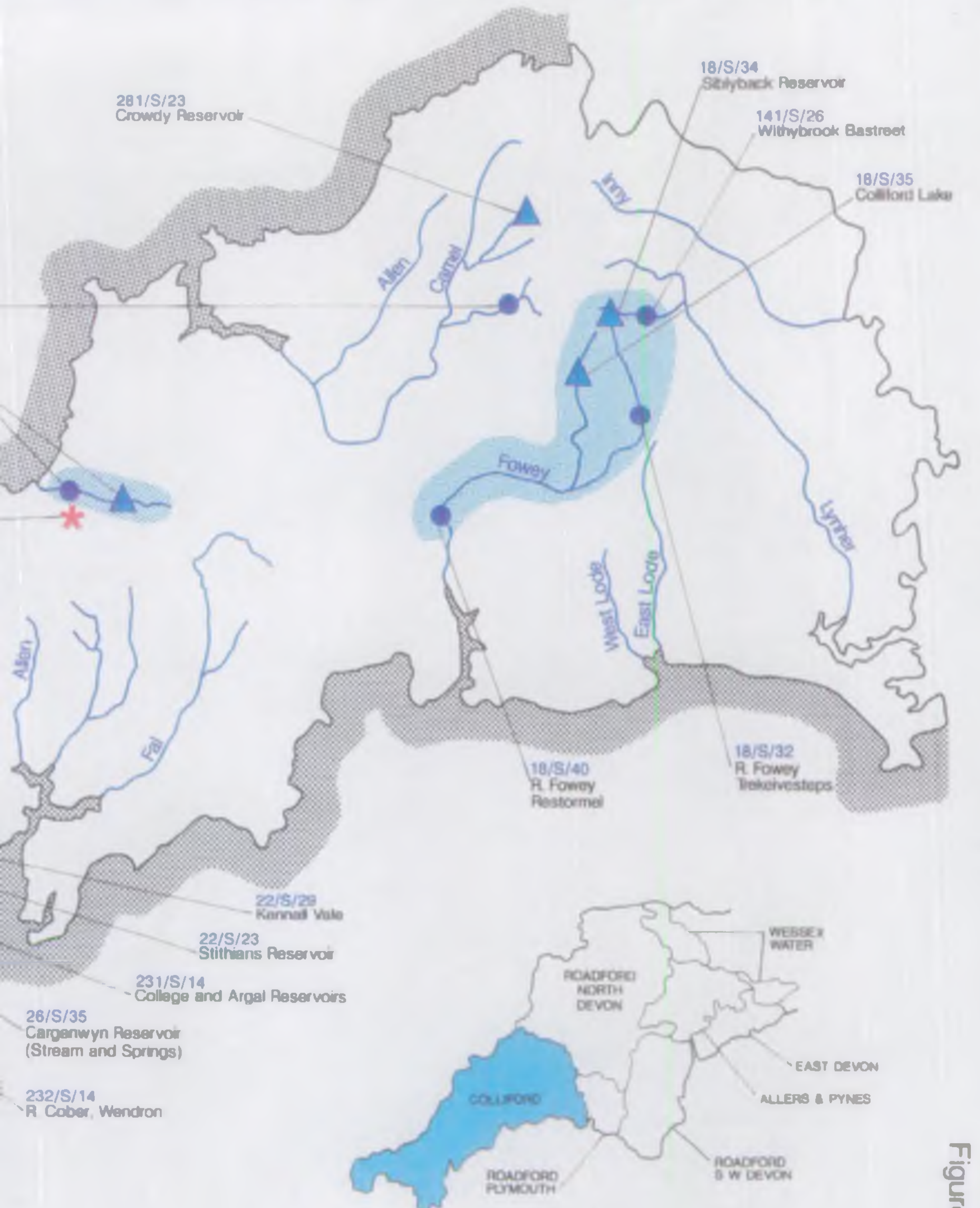


Figure 6

South West Water Services Ltd.
COLLIFORD SUPPLY ZONE
Public Water Supply Sources

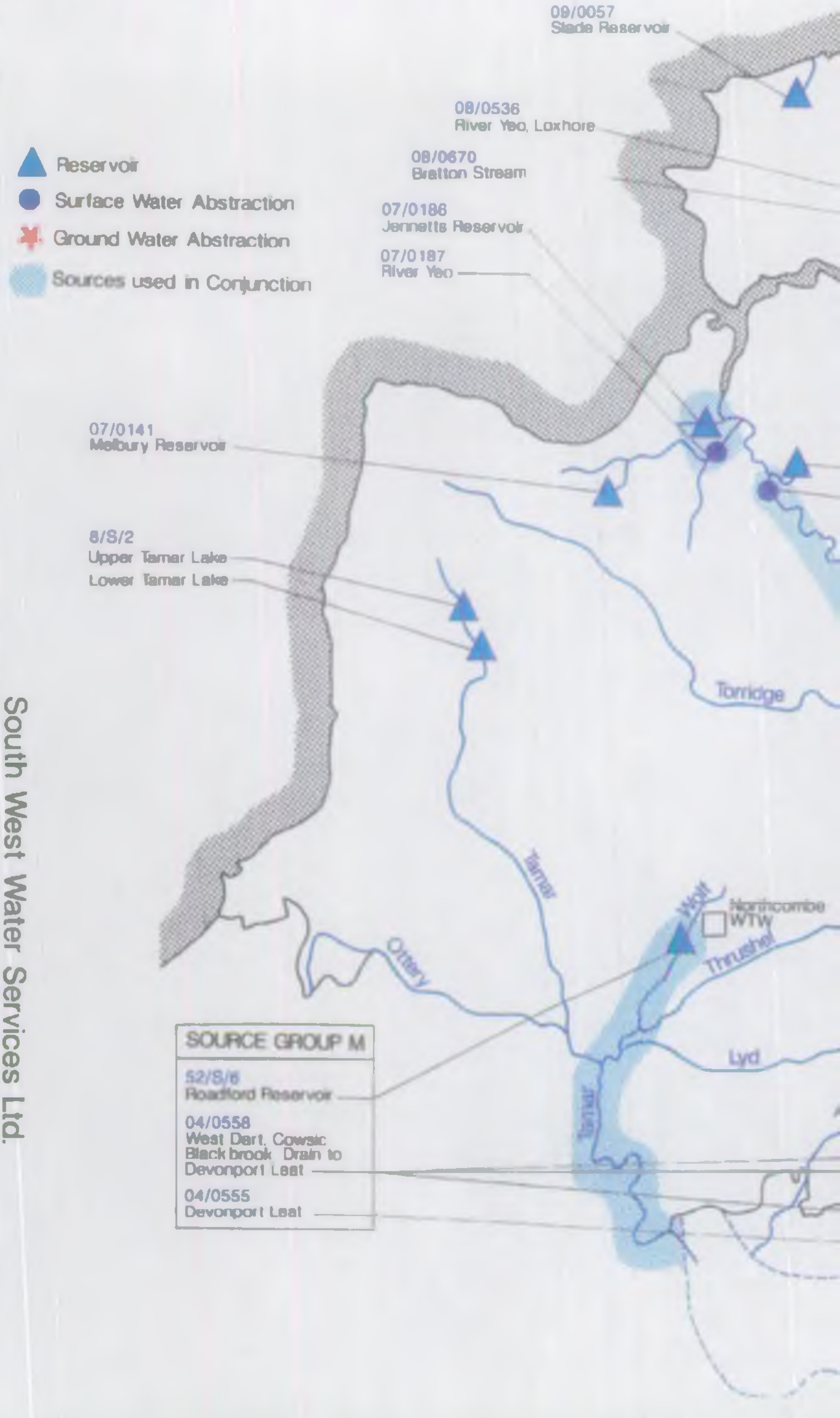




281/S/23
Crowdy Reservoir
18/S/34
Siblyback Reservoir
141/S/26
Withybrook Bastreet
18/S/35
Colliford Lake
Inny
Allen
Camel
Fowey
Lynher
West Lode
East Lode
Allen
Fal
18/S/40
R. Fowey
Restormel
18/S/32
R. Fowey
Trekeivesteps
22/S/29
Kennall Vale
22/S/23
Stithians Reservoir
231/S/14
College and Argal Reservoirs
26/S/35
Carganwyn Reservoir
(Stream and Springs)
232/S/14
R. Cober, Wendron
WESSEX
WATER
ROADFORD
NORTH
DEVON
COLLIFORD
EAST DEVON
ALLERS & PYNES
ROADFORD
PLYMOUTH
ROADFORD
S W DEVON

Figure 7

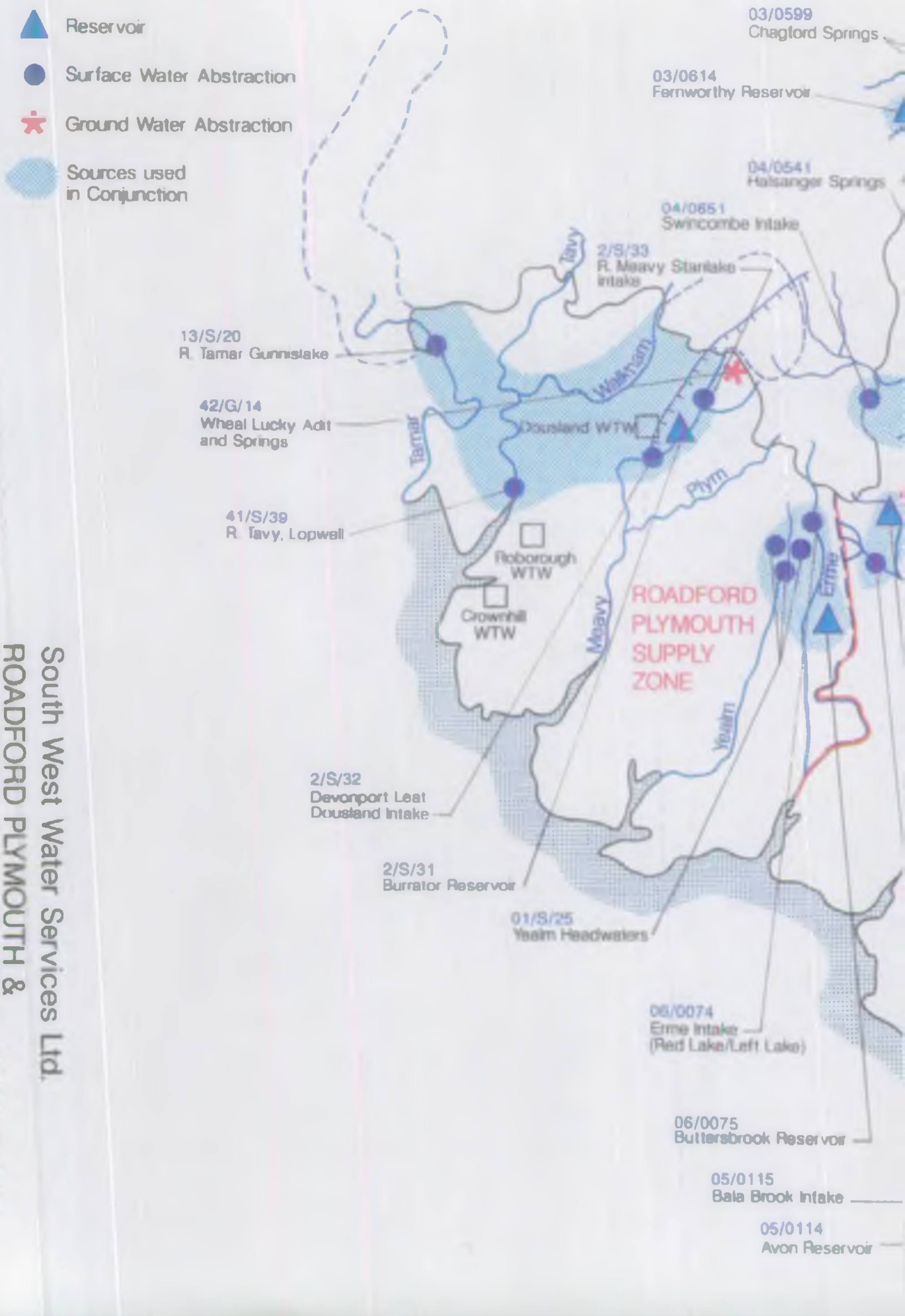
South West Water Services Ltd.
ROADFORD NORTH DEVON SUPPLY ZONE
Public Water Supply Sources

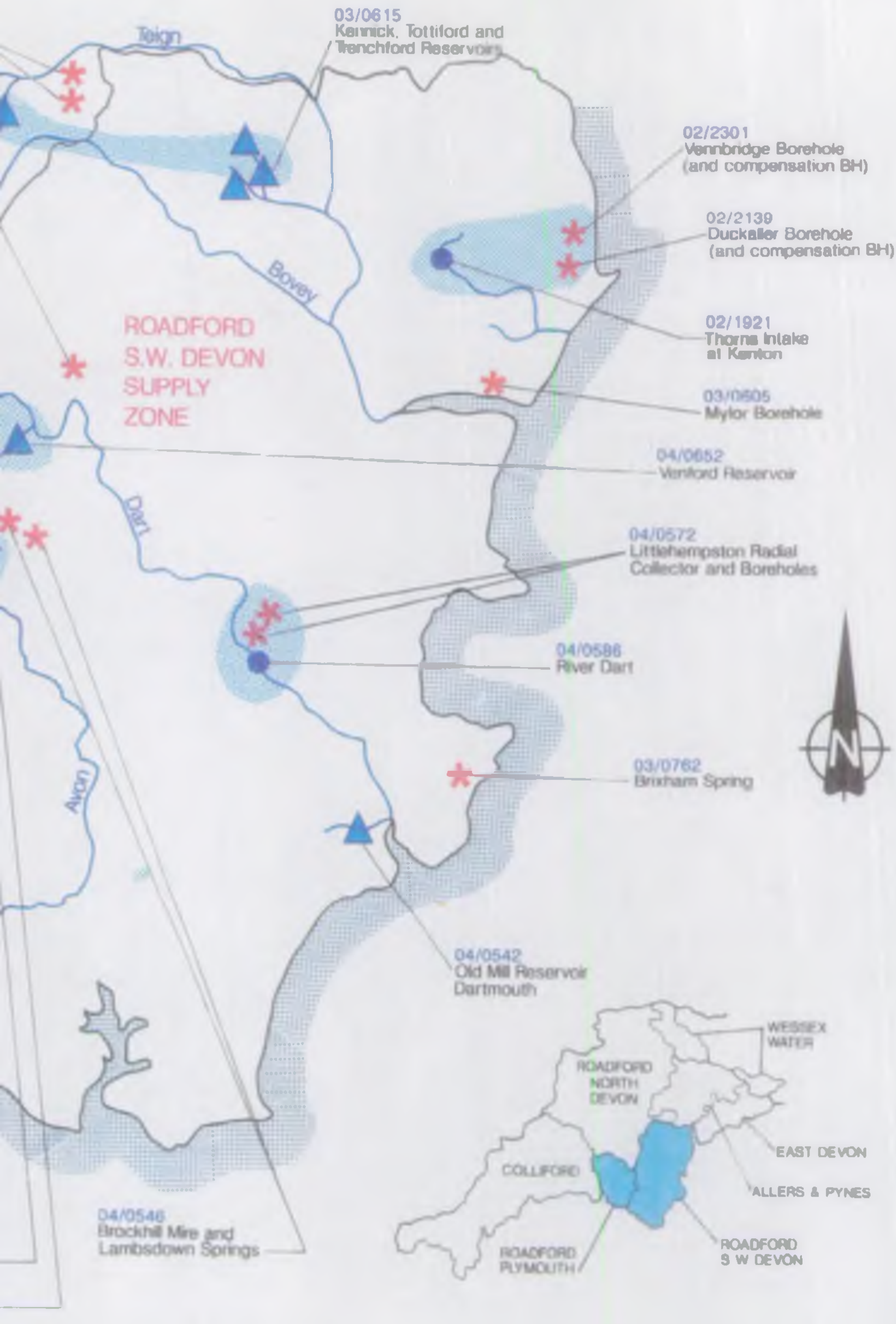


09/0056
West Ilkerton River
08/0696
Brockenburrow Intake
08/0694
River Bray, Leehamford
08/0695
Wistlandpound Reservoir
08/0725
Spreycott Stream
08/0535
Holywell Reservoir
08/0713
R. Taw, Newbridge
07/0135
Gammaton Reservoir
07/0173
R. Torridge, Torrington
08/0563
Taw Marsh Boreholes
07/0136
Red-a-ven/Black-a-ven
07/0167
W. Okement/Meldon Reservoir
Barnstable
Yeo
Taw
Bray
Yeo
Mole
Taw
Walkham
Dart
N
WESSEX WATER
ROADFORD NORTH DEVON
EAST DEVON
ALLERS & PYNES
COLLIFORD
ROADFORD S W DEVON
ROADFORD PLYMOUTH

Figure 8

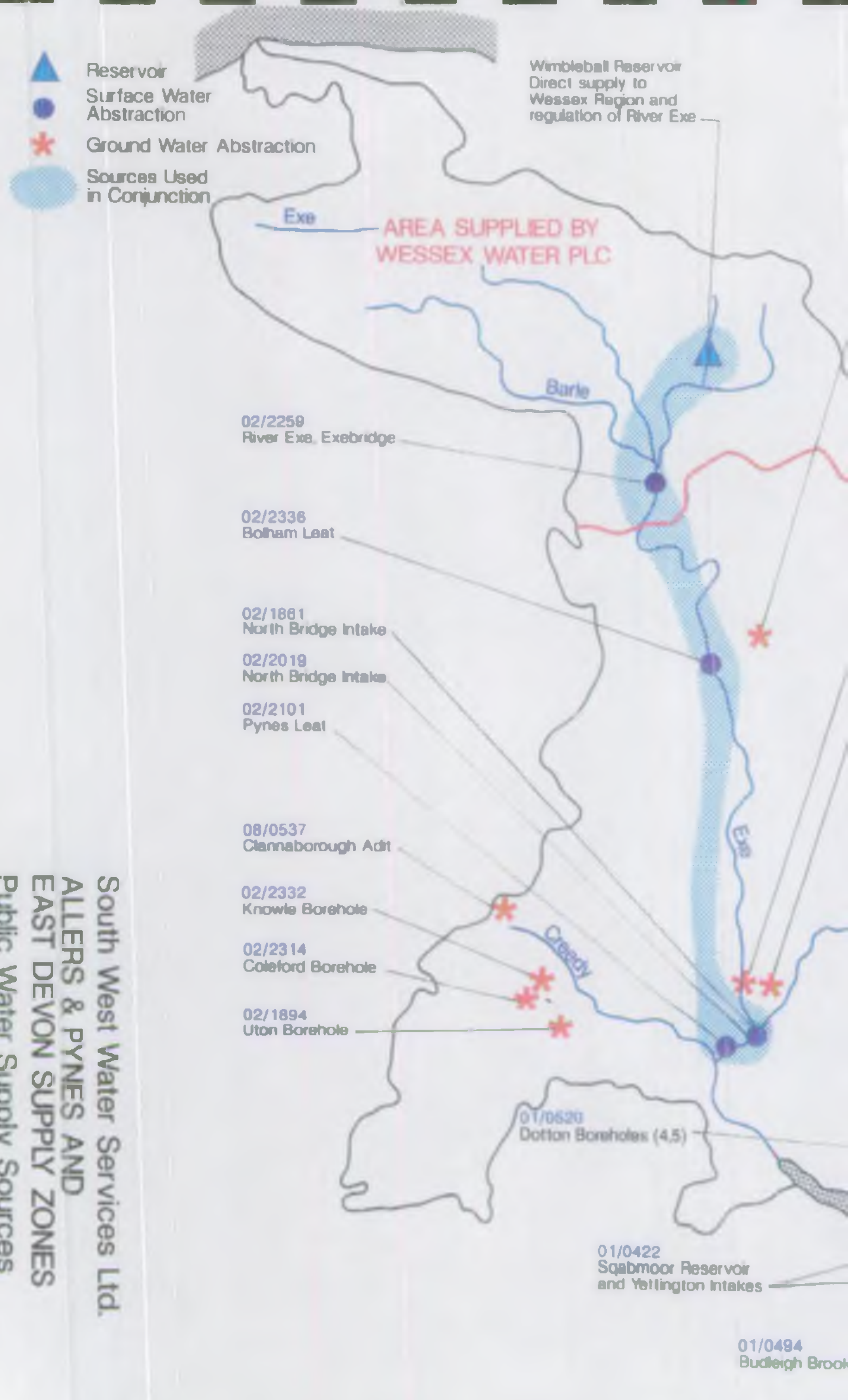
South West Water Services Ltd.
ROADFORD PLYMOUTH &
ROADFORD S. W. DEVON SUPPLY ZONES
Public Water Supply Sources





Teign
03/0615
Kennick, Tottiford and Trenchford Reservoirs
Bovey
02/2301
Vennbridge Borehole (and compensation BH)
02/2139
Duckaller Borehole (and compensation BH)
02/1921
Thorns Intake at Kenton
ROADFORD S.W. DEVON SUPPLY ZONE
03/0605
Mylor Borehole
04/0652
Venford Reservoir
Dart
04/0572
Littlehempston Radial Collector and Boreholes
04/0586
River Dart
N
03/0762
Brixham Spring
Avon
04/0542
Old Mill Reservoir Dartmouth
WESSEX WATER
ROADFORD NORTH DEVON
EAST DEVON
COLLIFORD
ALLERS & PYNES
ROADFORD S W DEVON
ROADFORD PLYMOUTH
04/0546
Brockhill Mire and Lambsdown Springs

Figure 9

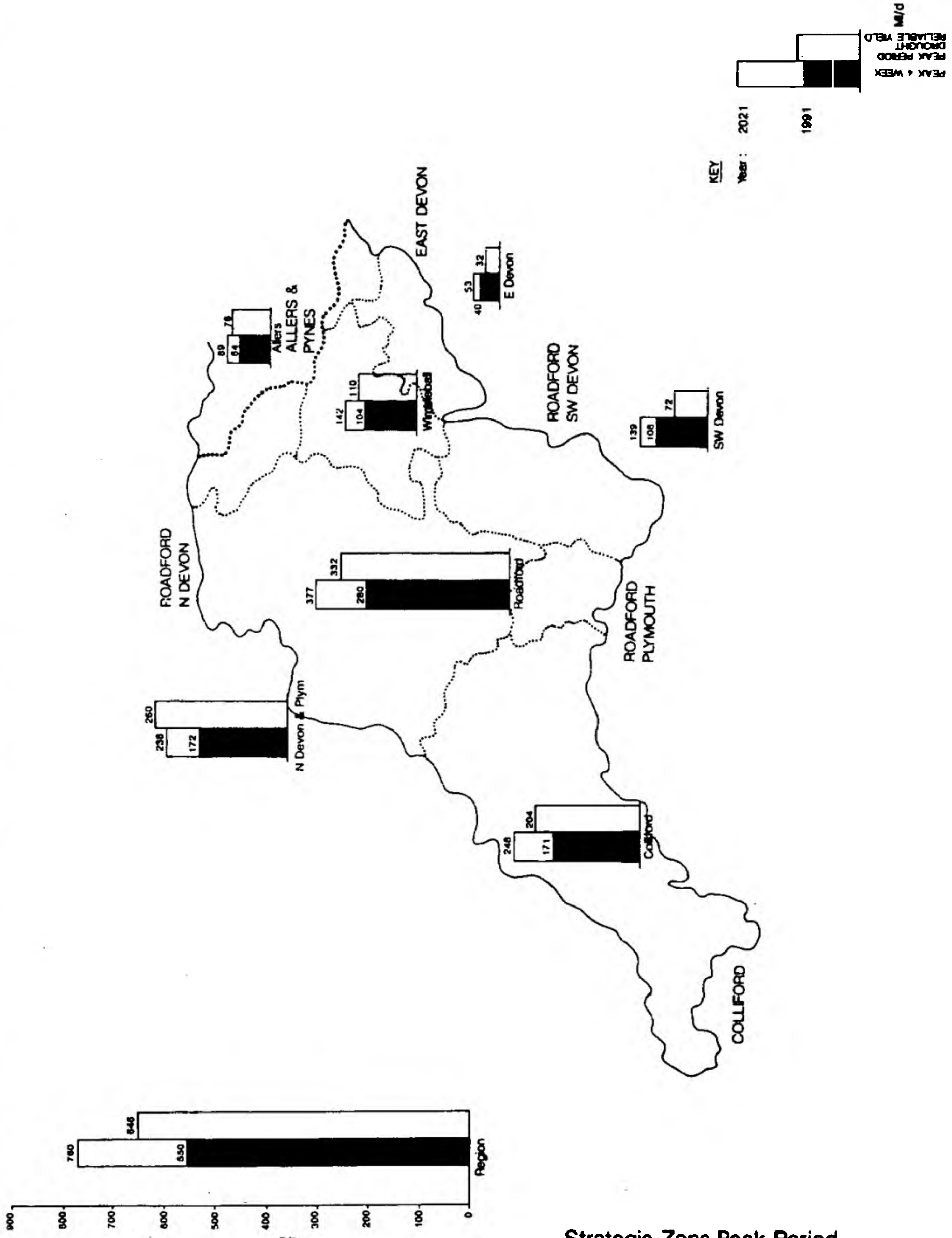


South West Water Services Ltd.
ALLERS & PYNES AND
EAST DEVON SUPPLY ZONES
Public Water Supply Sources

02/0083
Aller Springs
02/1825
Brampford Speke Borehole
02/1863
Stoke Canon Borehole
02/1881
Sheldon Springs
01/0505
Greatwell No. 5 Borehole
01/0426
Greatwell Boreholes (1,2,3,)
01/0414
Greatwell 4B Borehole
01/0417
St. Cyres Spring
00/0676
Hook and Cotley Springs
WESSEX WATER
ROADFORD NORTH DEVON
EAST DEVON
ALLERS & PYNES
COLLIFORD
ROADFORD S W DEVON
ROADFORD PLYMOUTH
AREA SUPPLIED BY WESSEX WATER PLC
ALLERS & PYNES SUPPLY ZONE
Culm
Otter
Yarty
Axe
Sid
00/0669
Wilmington Springs
00/0835
River Axe Whitford Bridge
00/0679
Bovey Lane Boreholes
00/0790
Pinhay Springs
EAST DEVON SUPPLY ZONE
00/0678
Holyford Ponds
00/0677
Couchill Springs
01/0418
Sidford 3 Borehole
01/0518
Harpford Boreholes
01/0478
Colaton Raleigh Boreholes 2 & 4
01/0519
Dotton Boreholes (1,2,3,7)
01/0544
Otterton Boreholes 1A & 4
01/0425
Kersbrook Spring

Figure 10

Figure 11



Strategic Zone Peak Period
Water Supply Surplus/Deficit :
Scenario 1 Excluding 5% Planning Margin

Average Household Water Use.

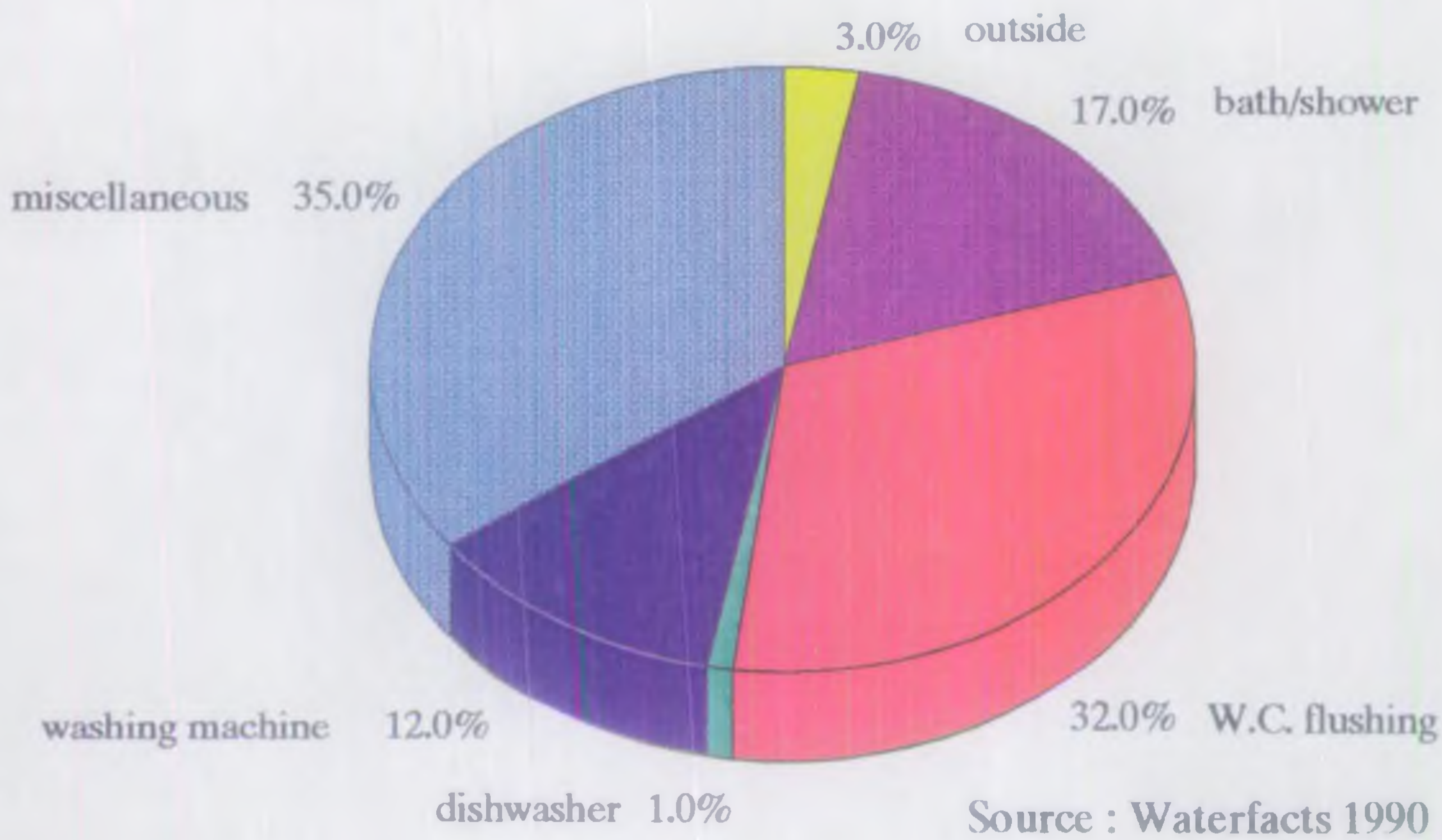
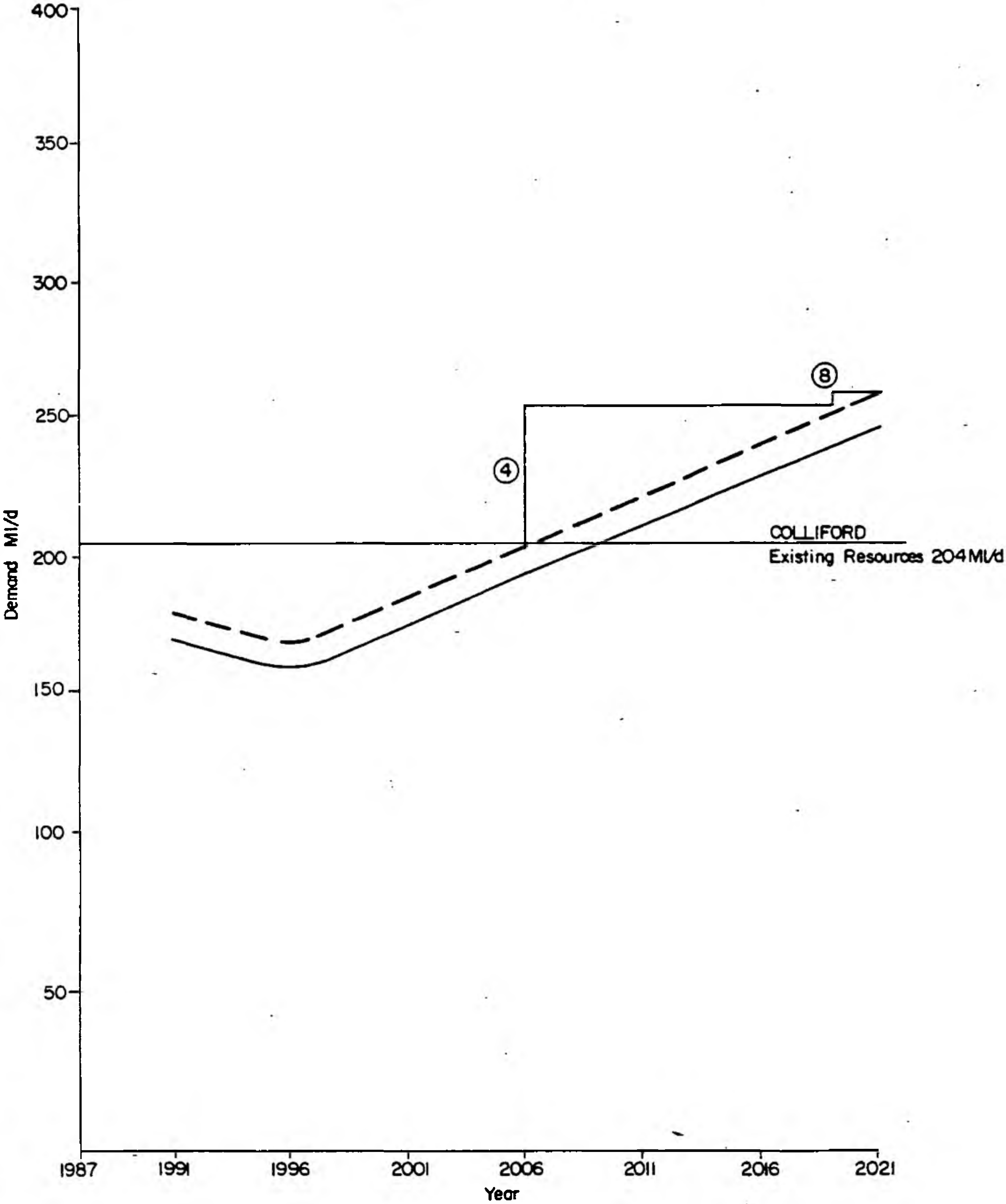


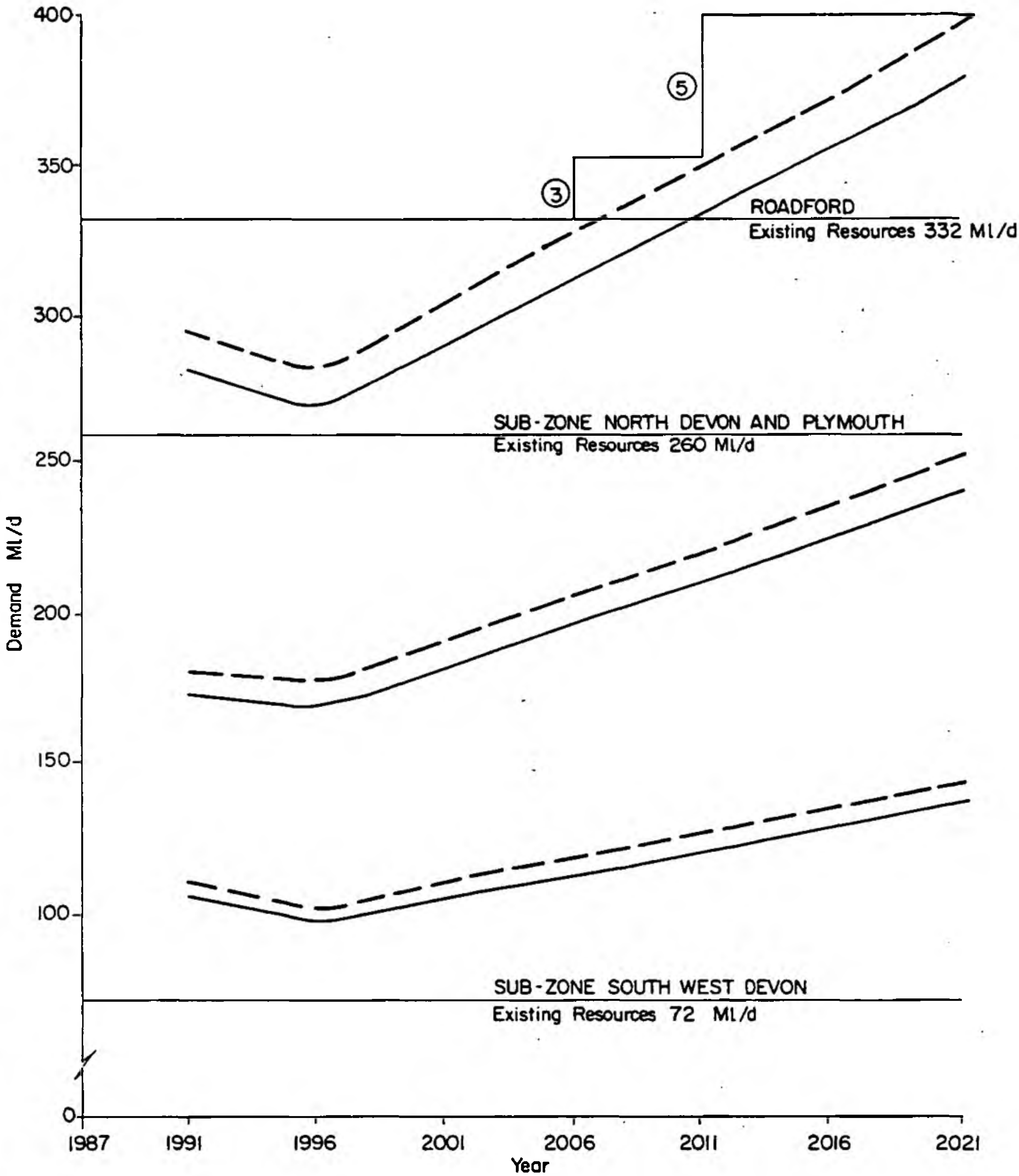
Figure 12

Figure 13



KEY - See Figure 17

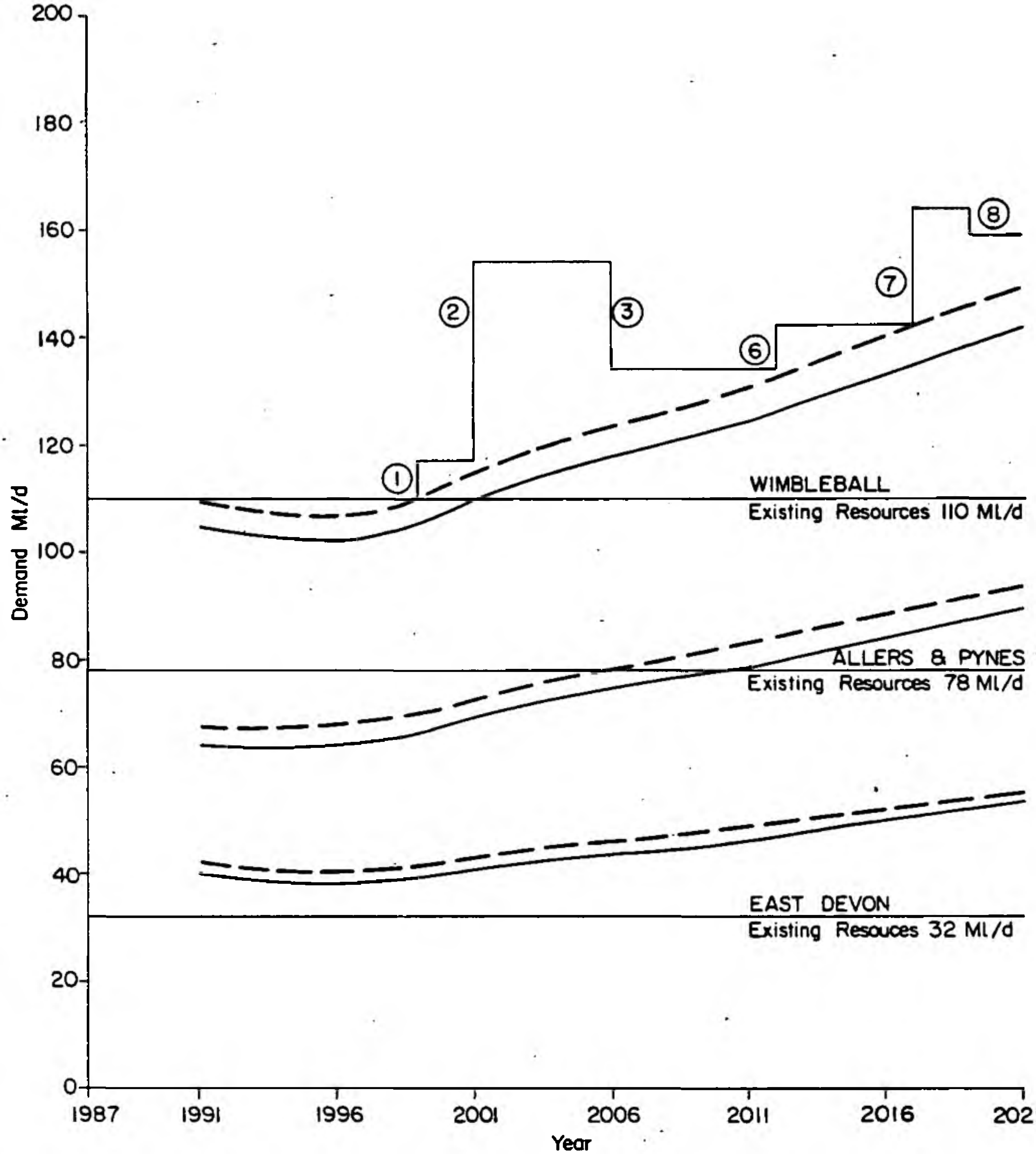
COLLIFORD STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 1



KEY - See Figure 17

ROADFORD STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 1

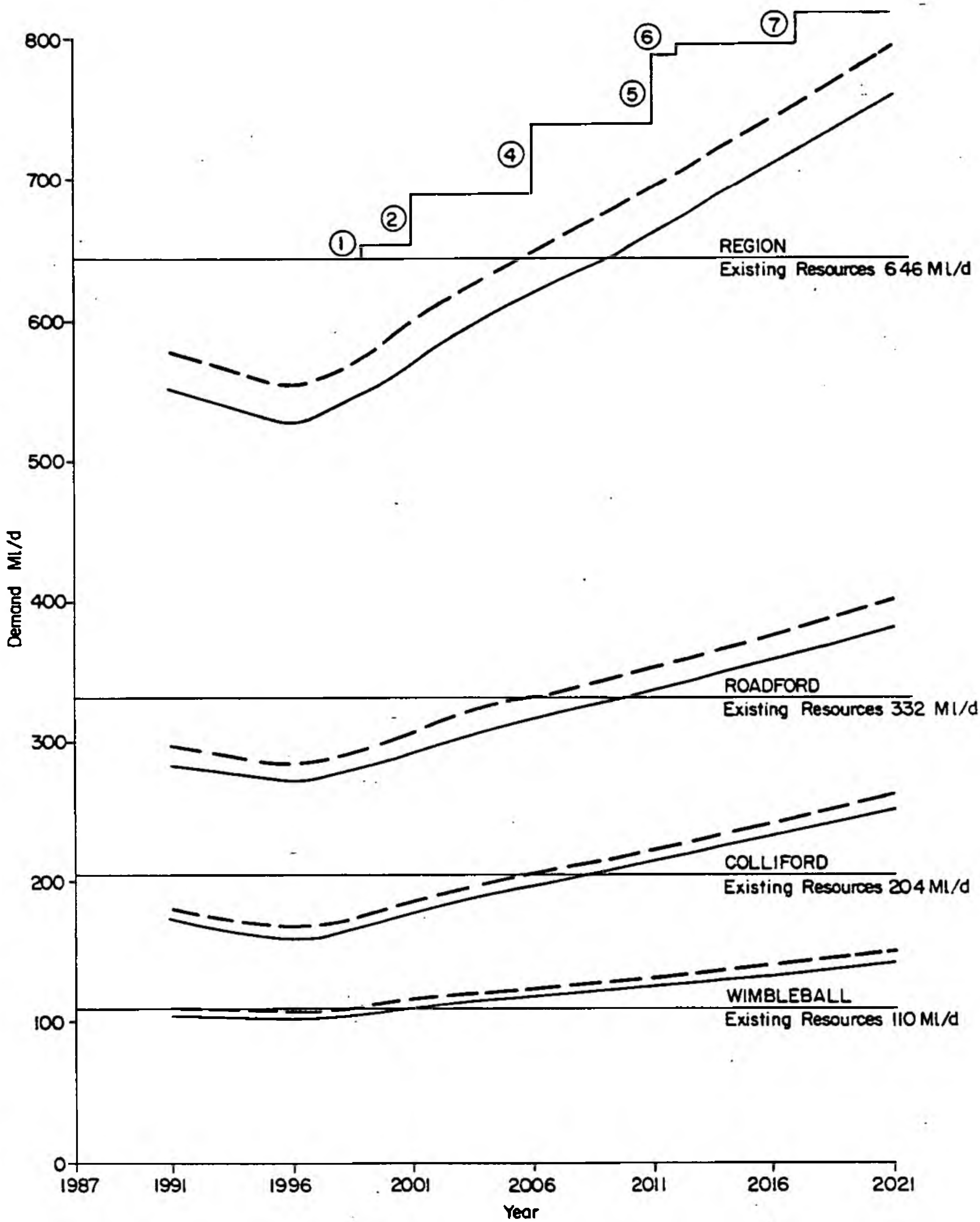
Figure 15



KEY - See Figure 17

WIMBLEBALL STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 1

Figure 16



KEY - See Figure 17

S.W.W.S.L. SUPPLY AREA
STRATEGY TO MEET DEMAND
SCENARIO 1

SCENARIO 1

	RESOURCE DEVELOPMENTS	YIELD Ml/d	YEAR
1	OTTER BOREHOLES	7	1999
2	WIMBLEBALL PUMPED STORAGE	37	2001
3	20Ml/d TRANSFER FROM ALLERS & PYNES TO ROADFORD	-	2006
4	COLLIFORD PUMPED STORAGE	50	2006
5	ROADFORD PUMPED STORAGE	50	2011
6	RIVER CREEDY OR CULM ABSTRACTION	7	2012
7	AXE PUMPED STORAGE RESERVOIR	22	2017
8	5Ml/d TRANSFER FROM ALLERS & PYNES TO ROADFORD AND A CORRESPONDING 5Ml/d TRANSFER FROM ROADFORD TO COLLIFORD	-	2019
	TOTAL NEW RESOURCES	173Ml/d	

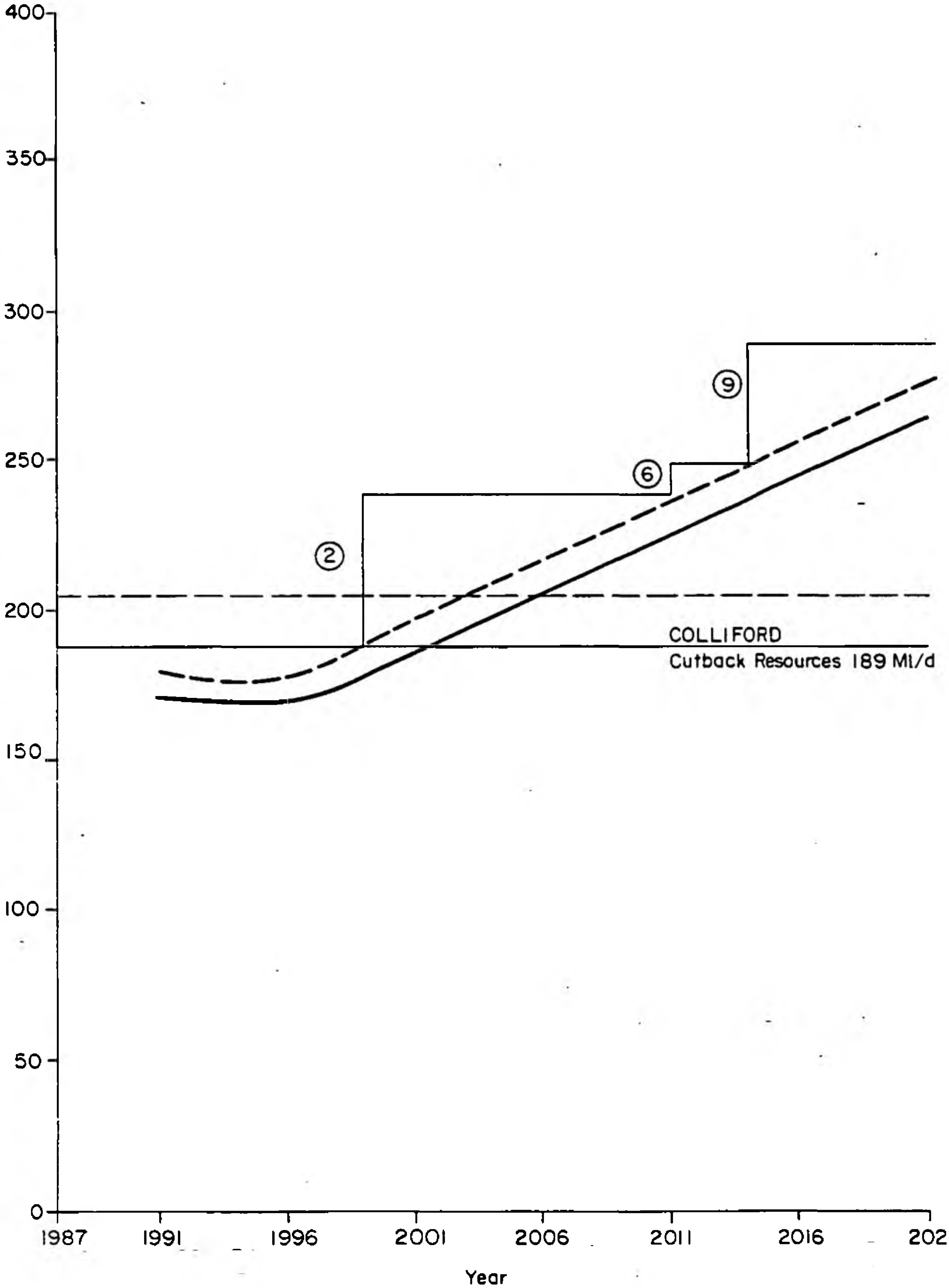
2021 PLANNING DEFICITS	COLLIFORD	-57
	ROADFORD	-68
	WIMBLEBALL	-39
	TOTAL	-164Ml/d

2021 SURPLUS RESOURCE 173 - 164 = 9 Ml/d

KEY to Figures 13 - 16

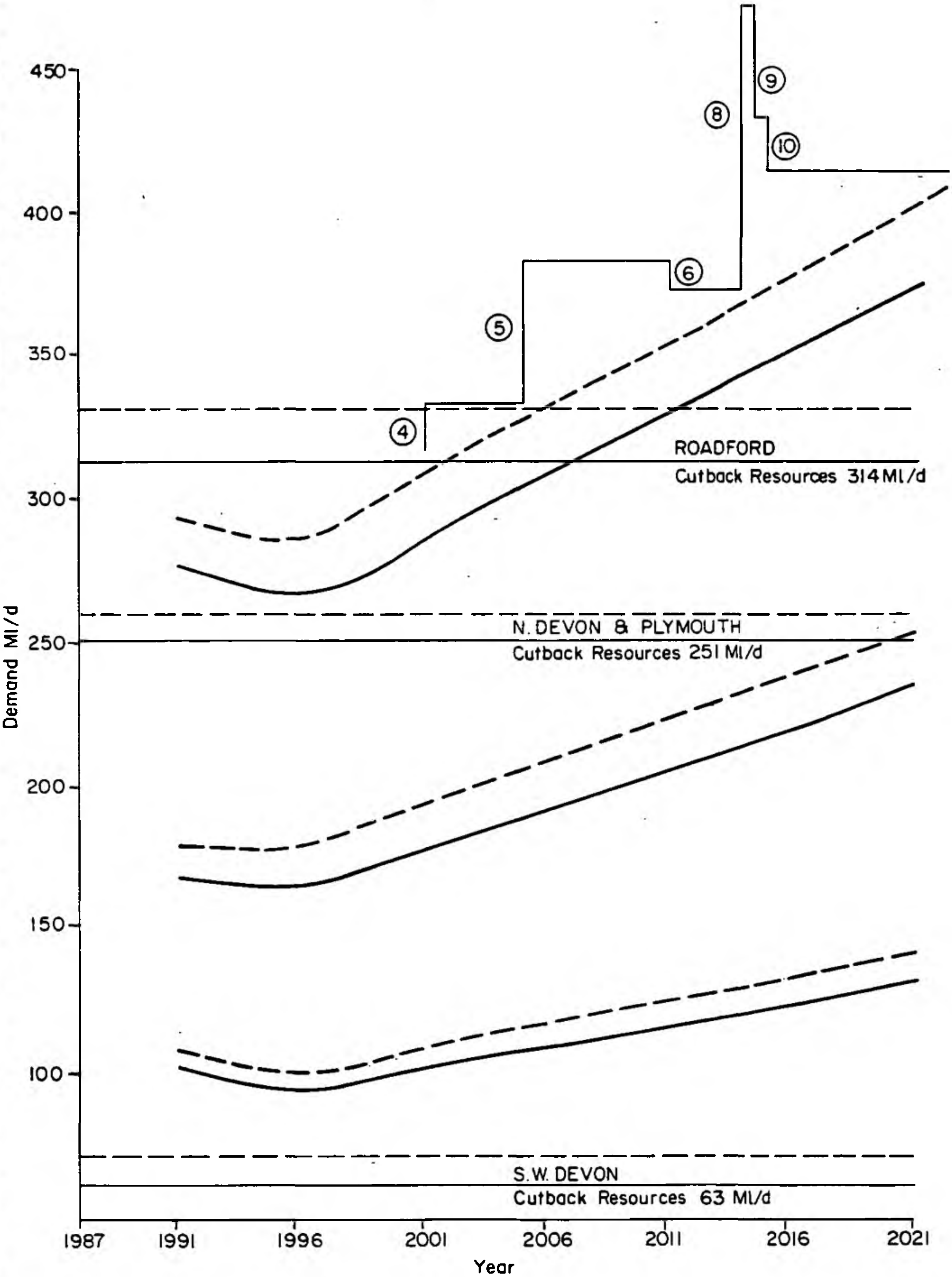
— — — — Likely Demand with 5% Planning Margin

———— Likely Demand



KEY - See Figure 22

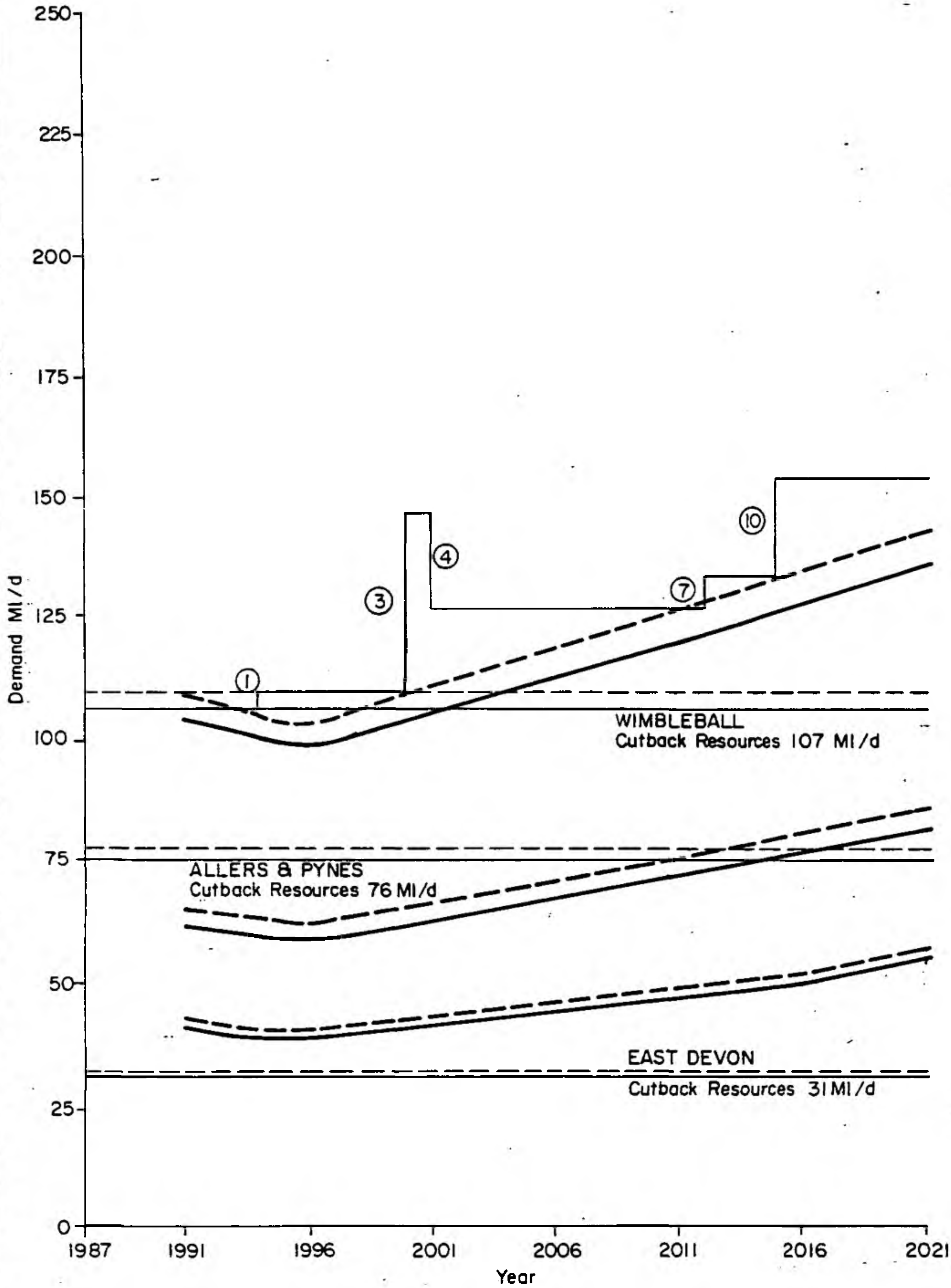
COLLIFORD STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 2



KEY - See Figure 22

ROADFORD STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 2

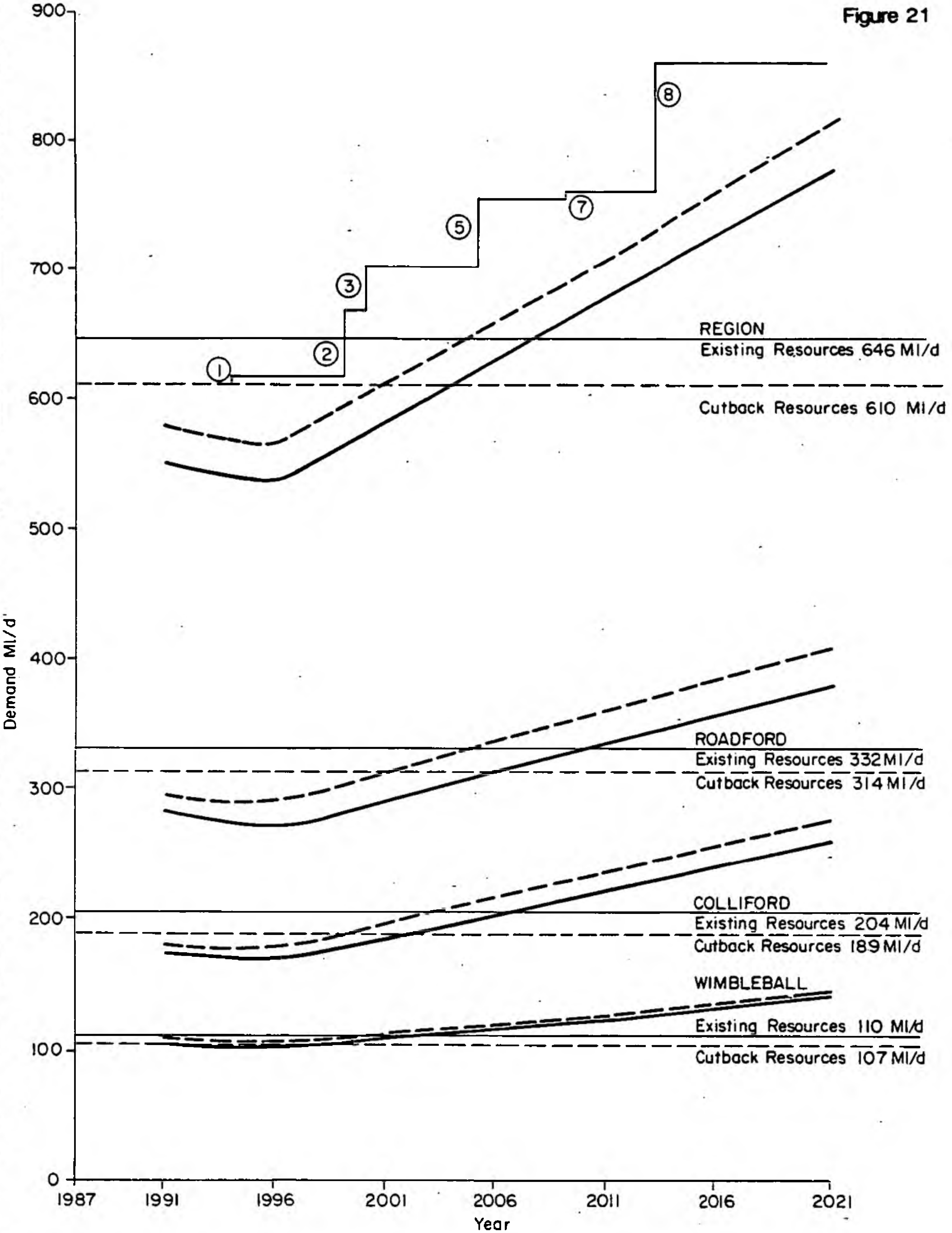
Figure 20



KEY - See Figure 22

WIMBLEBALL STRATEGIC ZONE
STRATEGY TO MEET DEMAND
SCENARIO 2

Figure 21



KEY - See Figure 22

S.W.W.S.L. SUPPLY AREA
STRATEGY TO MEET DEMAND
SCENARIO 2

SCENARIO 2

	RESOURCE DEVELOPMENTS	YIELD Ml/d	YEAR
1	OTTER BOREHOLES	7	1994
2	COLLIFORD PUMPED STORAGE	50	1999
3	WIMBLEBALL PUMPED STORAGE	37	2000
4	20Ml/d EXPORT FROM WIMBLEBALL TO ROADFORD	-	2001
5	ROADFORD PUMPED STORAGE	50	2005
6	10Ml/d EXPORT FROM ROADFORD TO COLLIFORD	-	2011
7	R CREEDY/CULM ABSTRACTION	7	2012
8	NEW ROADFORD RESERVOIR	100	2014
9	40Ml/d ADDITIONAL EXPORT FROM ROADFORD TO COLLIFORD	-	2014
10	20Ml/d REDUCTION IN EXPORT FROM WIMBLEBALL TO ROADFORD	-	2015
	TOTAL NEW RESOURCES	251Ml/d	

2021 PLANNING DEFICITS	COLLIFORD	-88
	ROADFORD	-97
	WIMBLEBALL	-36
	TOTAL	-221Ml/d

2021 SURPLUS RESOURCE 251 - 221 = 30Ml/d

KEY to Figures 18 -21

- – – – Likely Demand with 5% Planning Margin
- ——— Likely Demand
- – – – Existing Resources
- ——— Cutback Resources

Appendix A

TERMS OF REFERENCE

HALCROW

TERMS OF REFERENCE

The purpose of the study is to review the public water resource strategy for the South West region, including the Colliford, Roadford, Wimbleball and East Devon supply areas.

To achieve this, it will be necessary to:

a) review forecasts of water demand in those supply areas;

b) confirm where and when, shortfalls between existing available resources and forecast demands are likely to occur;

c) develop alternative resource development strategies to overcome such shortfalls;

d) compare these strategies through a consistent evaluation of the environmental impact, yield and cost of each component scheme within them;

e) identify the preferred strategies in:

   i) super regional (South West and Wessex) terms;

   ii) regional (South West only) terms;

f) report on the various studies and findings.

APPROACH

The study will be carried out by making best use of available data. Thus a main task will be to collect and collate work done on demand forecasting and resource planning, as well as information on the yield, performance and distribution system constraints of existing sources. Much of these data will originate from South West Water plc and Wessex Water plc and it will save considerable time and effort if these bodies can be consulted directly as the study proceeds.

Water demand forecasts will be reviewed to check:

- that a reasonable and consistent approach has been adopted in their preparation;
- that they can be subdivided into appropriate zonal or subzonal constituencies to facilitate comparison with individual/groups of existing sources;
- their sensitivity to differing assumptions on leakage control, charging policy, residential/commercial growth patterns and other key factors.

Choice of planning horizon for the study is subject to discussion, but for present purposes it is assumed to be the year 2016.

The review of existing resources will take into account:

- source yields and performance as currently understood by the operators;
- constraints on yield such as treatability, treatment works capacity, river flow, adverse environmental impact and operating rules;
- the distribution system into which the source feeds, insofar as this may govern source utilisation.

Source yields will not be evaluated from scratch.

The objective of the demand forecast and existing resource reviews is to audit the demand/yield information and hence to identify those areas in the region where deficits may occur within the planning horizon.

A number of potential resource developments have been identified and studied in the project area. In assembling this proposal, it has been assumed that no new scheme identification studies will be necessary. Work in this area will thus focus on existing reports and data. These include, inter alia:

Water supplies for SW Devon - Hydrological Feasibility Study	DRA/Halcrow (1972)
Somerset Water Resources Study	WWA/Halcrow
Wimbleball Pumped Storage Scheme	SWWA/Halcrow
Exe Resources EIA	SWWA/Halcrow
Dart Resources EIA	SWWA/Halcrow
River Bray Operational & Environmental Study	SWWA/Halcrow
Roadford Operational & Environmental Study	NRA/SWW/Halcrow
River Axe Scheme	SWW/MRM

Schemes identified in such reports will be reviewed in terms of yield, environmental impact, cost and proximity to areas of forecast deficit.
The more promising schemes will be used to assemble alternative development strategies; these will be compared in order to identify the best option, taking into account optimisation of available resources.

On the basis of the foregoing work and in consultation with the interested parties, recommendations for a future water resource development strategy in the project area will be prepared.

Appendix B

DEMAND FORECASTS FOR SWWSL SUPPLY AREA

HALCROW

TABLE B1 - LIKELY DEMAND FORECASTS (Ml/D)

	1991	1996	2001	2006	2011	2016	2021
UNMEASURED TOURIST+MISC (LIKLEY)							
COLLIFORD	4.93	5.48	6.05	6.63	7.23	7.84	8.48
N.DEVON.	1.12	1.24	1.36	1.49	1.62	1.76	1.90
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	3.55	3.84	4.14	4.43	4.71	5.01	5.33
ALLERS	0.53	0.56	0.59	0.63	0.67	0.70	0.74
E.DEVON	0.40	0.43	0.46	0.49	0.53	0.56	0.60
TOTAL	10.53	11.54	12.60	13.67	14.75	15.87	17.05
% UNMEASURED TOURIST+MISC (LIKLEY)							
COLLIFORD	0.03	0.04	0.04	0.04	0.04	0.04	0.04
N.DEVON	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	0.04	0.05	0.05	0.05	0.05	0.05	0.05
ALLERS	0.01	0.01	0.01	0.01	0.01	0.01	0.01
E.DEVON	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	0.02	0.02	0.02	0.02	0.02	0.02	0.02
UNMEASURED DOMESTIC (LIKELY)							
COLLIFORD	60.23	66.99	74.14	81.43	89.12	97.17	105.63
N.DEVON	24.95	27.21	29.59	32.54	35.36	38.59	41.98
PLYMOUTH	44.51	48.28	52.23	55.80	59.29	62.99	66.90
S.W.DEVON	39.13	42.71	46.46	49.99	53.49	57.16	61.31
ALLERS	23.84	25.59	27.41	29.43	31.46	33.77	36.15
E.DEVON	15.27	16.57	17.93	19.35	20.79	22.40	24.15
TOTAL	207.93	227.35	247.77	268.53	289.51	312.07	336.11
% UNMEASURED DOMESTIC (LIKELY)							
COLLIFORD	0.40	0.48	0.48	0.48	0.48	0.49	0.49
N.DEVON	0.36	0.42	0.42	0.42	0.42	0.42	0.43
PLYMOUTH	0.49	0.51	0.52	0.53	0.53	0.54	0.54
S.W.DEVON	0.43	0.51	0.51	0.52	0.52	0.52	0.53
ALLERS	0.41	0.43	0.43	0.44	0.44	0.44	0.44
E.DEVON	0.42	0.48	0.48	0.49	0.49	0.49	0.50
TOTAL	0.42	0.48	0.48	0.48	0.49	0.49	0.49
LEAKAGE CONTROL (LIKELY)							
COLLIFORD	40.04	18.57	20.13	22.09	24.12	26.22	28.39
N.DEVON	19.33	8.72	9.32	10.24	11.15	12.11	13.11
PLYMOUTH	19.13	16.94	17.39	18.44	19.49	20.59	21.75
S.W.DEVON	25.30	13.29	14.33	15.32	16.30	17.31	18.42
ALLERS	16.01	13.22	14.11	15.06	16.01	17.05	18.10
E.DEVON	10.56	6.93	7.43	7.94	8.45	9.01	9.61
TOTAL	130.37	77.66	82.70	89.08	95.51	102.29	109.38
% LEAKAGE CONTROL (LIKELY)							
COLLIFORD	0.27	0.13	0.13	0.13	0.13	0.13	0.13
N.DEVON	0.28	0.14	0.13	0.13	0.13	0.13	0.13
PLYMOUTH	0.21	0.18	0.17	0.17	0.17	0.18	0.18
S.W.DEVON	0.28	0.16	0.16	0.16	0.16	0.16	0.16
ALLERS	0.27	0.22	0.22	0.22	0.22	0.22	0.22
E.DEVON	0.29	0.20	0.20	0.20	0.20	0.20	0.20
TOTAL	0.26	0.16	0.16	0.16	0.16	0.16	0.16

MEASURED (LIKELY)							
COLLIFORD	33.65	37.44	41.23	45.01	48.80	52.59	56.38
N.DEVON	21.43	23.99	26.55	29.12	31.68	34.24	36.80
PLYMOUTH	21.21	22.05	22.93	23.83	24.75	25.71	26.70
S.W.DEVON	18.53	19.67	20.80	21.93	23.07	24.20	25.33
ALLERS	15.86	17.09	18.31	19.54	20.77	21.99	23.22
E.DEVON	8.35	8.78	9.20	9.63	10.06	10.49	10.91
TOTAL	119.03	129.01	139.02	149.06	159.12	169.22	179.34

% MEASURED (LIKELY)							
COLLIFORD	0.23	0.27	0.27	0.27	0.27	0.26	0.26
N.DEVON	0.31	0.37	0.38	0.38	0.38	0.38	0.37
PLYMOUTH	0.23	0.24	0.23	0.23	0.22	0.22	0.22
S.W.DEVON	0.20	0.23	0.23	0.23	0.22	0.22	0.22
ALLERS	0.27	0.29	0.29	0.29	0.29	0.29	0.28
E.DEVON	0.23	0.25	0.25	0.24	0.24	0.23	0.23
TOTAL	0.24	0.27	0.27	0.27	0.27	0.26	0.26

UNMEASURED NON-DOMESTIC (LIKELY)							
COLLIFORD	9.96	11.07	12.23	13.41	14.63	15.88	17.18
N.DEVON	2.69	2.97	3.25	3.57	3.88	4.22	4.57
PLYMOUTH	6.07	6.53	7.01	7.44	7.87	8.32	8.80
S.W.DEVON	4.01	4.33	4.67	5.00	5.32	5.66	6.02
ALLERS	2.42	2.56	2.70	2.85	3.01	3.17	3.34
E.DEVON	2.01	2.16	2.31	2.47	2.63	2.81	2.99
TOTAL	27.15	29.62	32.18	34.74	37.34	40.06	42.90

UNMEASURED NON-DOMESTIC + TOURIST+MISC. (LIKELY)							
COLLIFORD	14.89	16.55	18.28	20.03	21.85	23.72	25.66
N.DEVON	3.81	4.20	4.61	5.07	5.50	5.98	6.47
PLYMOUTH	6.07	6.53	7.01	7.44	7.87	8.32	8.80
S.W.DEVON	7.56	8.17	8.81	9.42	10.03	10.66	11.36
ALLERS	2.95	3.12	3.29	3.48	3.67	3.88	4.08
E.DEVON	2.42	2.59	2.78	2.96	3.16	3.37	3.59
TOTAL	37.68	41.16	44.78	48.41	52.08	55.93	59.96

TOTAL WITH LEAKAGE CONTROL (LIKELY)							
COLLIFORD	148.89	139.55	153.78	168.57	183.89	199.70	216.06
N.DEVON	69.51	64.12	70.08	76.95	83.69	90.92	98.36
PLYMOUTH	90.91	93.80	99.56	105.51	111.41	117.61	124.15
S.W.DEVON	90.52	83.84	90.41	96.66	102.88	109.33	116.42
ALLERS	58.66	59.01	63.13	67.50	71.91	76.68	81.56
E.DEVON	36.60	34.87	37.33	39.88	42.45	45.26	48.26
TOTAL	495.09	475.19	514.28	555.08	596.23	639.50	684.80
CHECK	495.00	475.19	514.27	555.08	596.23	639.50	684.79
%CHECK	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CHECK %	38.62	42.10	45.71	49.35	53.02	56.87	60.89

LEAKAGE CONSTANT (LIKELY)							
COLLIFORD	45.34	50.46	55.77	61.17	66.76	72.55	78.53
N.DEVON	21.65	23.90	26.20	28.77	31.29	34.00	36.78
PLYMOUTH	19.13	20.65	22.24	23.68	25.10	26.60	28.26
S.W.DEVON	37.29	40.32	43.48	46.44	49.41	52.46	55.81
ALLERS	16.01	17.30	18.61	20.01	21.42	22.95	24.51
E.DEVON	10.56	11.34	12.15	12.99	13.84	14.76	15.75
TOTAL	149.97	163.96	178.45	193.06	207.81	223.32	239.64

TOTAL WITH LEAKAGE CONSTANT (LIKELY)							
COLLIFORD	154.20	171.44	189.42	207.65	226.53	246.03	266.20
N.DEVON	71.83	79.31	86.96	95.49	103.84	112.81	122.03
PLYMOUTH	90.91	97.51	104.41	110.75	117.02	123.63	130.65
S.W.DEVON	102.50	110.87	119.55	127.79	135.99	144.48	153.81
ALLERS	58.66	63.09	67.63	72.46	77.32	82.58	87.96
E.DEVON	36.60	39.28	42.06	44.93	47.84	51.01	54.40
TOTAL	514.70	561.49	610.03	659.06	708.54	760.54	815.05

% LEAKAGE CONSTANT (LIKELY)							
COLLIFORD	0.29	0.29	0.29	0.29	0.29	0.29	0.30
N.DEVON	0.30	0.30	0.30	0.30	0.30	0.30	0.30
PLYMOUTH	0.21	0.21	0.21	0.21	0.21	0.22	0.22
S.W.DEVON	0.36	0.36	0.36	0.36	0.36	0.36	0.36
ALLERS	0.27	0.27	0.28	0.28	0.28	0.28	0.28
E.DEVON	0.29	0.29	0.29	0.29	0.29	0.29	0.29
TOTAL	0.29	0.29	0.29	0.29	0.29	0.29	0.29

TABLE B2 - LOW DEMAND FORECASTS (Ml/D)

	1991	1996	2001	2006	2011	2016	2021
UNMEASURED TOURIST+MISC (LOW)							
COLLIFORD	4.92	5.43	5.96	6.50	7.06	7.64	8.23
N.DEVON	1.12	1.23	1.34	1.46	1.57	1.70	1.83
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	3.54	3.81	4.09	4.36	4.63	4.91	5.21
ALLERS	0.53	0.56	0.59	0.63	0.66	0.70	0.73
E.DEVON	0.40	0.43	0.46	0.48	0.51	0.54	0.58
TOTAL	10.50	11.45	12.43	13.43	14.44	15.48	16.58
%UNMEASURED TOURIST+MISC (LOW)							
COLLIFORD	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N.DEVON	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	0.04	0.05	0.05	0.05	0.05	0.05	0.05
ALLERS	0.01	0.01	0.01	0.01	0.01	0.01	0.01
E.DEVON	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	0.02	0.03	0.03	0.03	0.03	0.03	0.03
UNMEASURED DOMESTIC (LOW)							
COLLIFORD	60.06	66.38	73.05	79.90	87.09	94.62	102.52
N.DEVON	24.87	26.95	29.11	31.80	34.24	37.18	40.27
PLYMOUTH	44.45	48.06	51.83	55.25	58.61	62.14	65.91
S.W.DEVON	39.04	42.38	45.87	49.24	52.59	56.00	59.84
ALLERS&	23.79	25.41	27.09	29.01	30.91	33.02	35.19
E.DEVON	15.23	16.42	17.66	18.87	20.23	21.67	23.31
TOTAL	207.45	225.59	244.61	264.06	283.68	304.63	327.04
%UNMEASURED DOMESTIC (LOW)							
COLLIFORD	0.43	0.51	0.51	0.51	0.51	0.51	0.51
N.DEVON	0.38	0.45	0.45	0.45	0.45	0.45	0.45
PLYMOUTH	0.52	0.54	0.55	0.56	0.56	0.56	0.57
S.W.DEVON	0.46	0.54	0.54	0.54	0.55	0.55	0.55
ALLERS&	0.43	0.46	0.46	0.46	0.46	0.47	0.47
E.DEVON	0.44	0.50	0.51	0.51	0.51	0.52	0.52
TOTAL	0.45	0.51	0.51	0.51	0.51	0.51	0.52
LEAKAGE CONTROL (LOW)							
COLLIFORD	34.41	14.33	15.41	16.85	18.35	19.89	21.48
N.DEVON	16.44	6.70	7.10	7.77	8.41	9.11	9.83
PLYMOUTH	15.99	13.88	14.16	15.00	15.83	16.69	17.62
S.W.DEVON	21.80	10.66	11.46	12.22	12.99	13.76	14.60
ALLERS&	13.64	11.04	11.75	12.52	13.28	14.10	14.93
E.DEVON	9.08	5.72	6.11	6.48	6.89	7.32	7.79
TOTAL	111.37	62.34	65.97	70.83	75.74	80.87	86.24
% LEAKAGE CONTROL (LOW)							
COLLIFORD	0.25	0.11	0.11	0.11	0.11	0.11	0.11
N.DEVON	0.25	0.11	0.11	0.11	0.11	0.11	0.11
PLYMOUTH	0.19	0.16	0.15	0.15	0.15	0.15	0.15
S.W.DEVON	0.26	0.13	0.13	0.13	0.13	0.13	0.13
ALLERS&	0.25	0.20	0.20	0.20	0.20	0.20	0.20
E.DEVON	0.26	0.18	0.18	0.18	0.18	0.18	0.18
TOTAL	0.24	0.14	0.14	0.14	0.14	0.14	0.14

MEASURED (LOW)							
COLLIFORD	30.63	34.06	37.52	40.96	44.41	47.86	51.30
N.DEVON	19.50	21.83	24.17	26.50	28.83	31.18	33.49
PLYMOUTH	19.30	20.07	20.87	21.68	22.32	23.40	24.29
S.W.DEVON	16.86	17.90	18.93	19.96	20.99	22.02	23.05
ALLERS&	14.44	15.55	16.67	17.78	18.90	20.01	21.13
E.DEVON	7.59	7.99	8.37	8.76	9.15	9.54	9.93
TOTAL	108.32	117.39	126.52	135.64	144.59	154.01	163.20

% MEASURED (LOW)							
COLLIFORD	0.22	0.26	0.26	0.26	0.26	0.26	0.26
N.DEVON	0.30	0.37	0.37	0.37	0.38	0.37	0.37
PLYMOUTH	0.22	0.23	0.22	0.22	0.21	0.21	0.21
S.W.DEVON	0.20	0.23	0.22	0.22	0.22	0.21	0.21
ALLERS&	0.26	0.28	0.28	0.28	0.28	0.28	0.28
E.DEVON	0.22	0.24	0.24	0.24	0.23	0.23	0.22
TOTAL	0.23	0.26	0.26	0.26	0.26	0.26	0.26

UNMEASURED NON-DOMESTIC (LOW)							
COLLIFORD	9.93	10.98	12.06	13.16	14.29	15.47	16.68
N.DEVON	2.68	2.94	3.21	3.50	3.77	4.08	4.39
PLYMOUTH	6.06	6.49	6.95	7.37	7.78	8.21	8.66
S.W.DEVON	4.00	4.30	4.62	4.92	5.23	5.54	5.88
ALLERS&	2.42	2.55	2.69	2.84	2.99	3.15	3.30
E.DEVON	2.00	2.14	2.28	2.41	2.57	2.71	2.89
TOTAL	27.09	29.40	31.79	34.20	36.64	39.15	41.80

% UNMEASURED NON-DOMESTIC (LOW)							
COLLIFORD	0.07	0.08	0.08	0.08	0.08	0.08	0.08
N.DEVON	0.04	0.05	0.05	0.05	0.05	0.05	0.05
PLYMOUTH	0.07	0.07	0.07	0.07	0.07	0.07	0.07
S.W.DEVON	0.05	0.05	0.05	0.05	0.05	0.05	0.05
ALLERS&	0.04	0.05	0.05	0.05	0.04	0.04	0.04
E.DEVON	0.06	0.07	0.07	0.07	0.07	0.06	0.06
TOTAL	0.06	0.07	0.07	0.07	0.07	0.07	0.07

TOTAL WITH LEAKAGE CONTROL (LOW)							
COLLIFORD	139.94	131.18	143.99	157.37	171.20	185.46	200.21
N.DEVON	64.62	59.65	64.92	71.02	76.82	83.23	89.82
PLYMOUTH	85.80	88.50	93.80	99.29	104.74	110.44	116.49
S.W.DEVON	84.79	79.04	84.95	90.70	96.43	102.74	108.57
ALLERS	54.82	55.11	58.78	62.78	66.74	70.97	75.28
E.DEVON	34.31	32.69	34.87	37.00	39.35	41.79	44.50
TOTAL	464.27	446.18	481.32	518.16	555.29	594.62	634.86
CHECK	464.73	446.17	481.32	518.16	555.09	594.13	634.86
CHECK%	1.00	1.00	1.00	1.00	1.00	1.00	1.00

LEAKAGE CONSTANT (LOW)							
COLLIFORD	39.13	43.32	47.66	52.11	56.71	61.45	66.36
N.DEVON	18.51	20.33	22.19	24.27	26.24	28.42	30.67
PLYMOUTH	15.99	17.21	18.50	19.65	20.79	21.98	23.32
S.W.DEVON	32.63	35.16	37.77	40.29	42.81	45.35	48.11
ALLERS&	13.64	14.68	15.73	16.88	18.03	19.25	20.50
E.DEVON	9.08	9.72	10.38	11.00	11.72	12.45	13.26
TOTAL	128.99	140.42	152.23	164.20	176.28	188.90	202.22

TOTAL WITH LEAKAGE CONSTANT (LOW)

COLLIFORD	144.66	160.17	176.25	192.63	209.56	227.02	245.09
N.DEVON	66.68	73.28	80.01	87.52	94.65	102.54	110.65
PLYMOUTH	85.80	91.84	98.14	103.94	109.71	115.73	122.19
S.W.DEVON	95.63	103.54	111.27	118.77	126.25	134.33	142.08
ALLERS&	54.82	58.75	62.77	67.15	71.48	76.12	80.86
E.DEVON	34.31	36.69	39.14	41.53	44.17	46.92	49.97
TOTAL	481.89	524.26	567.58	611.53	655.83	702.66	750.84

% LEAKAGE CONSTANT (LOW)

COLLIFORD	0.27	0.27	0.27	0.27	0.27	0.27	0.27
N.DEVON	0.28	0.28	0.28	0.28	0.28	0.28	0.28
PLYMOUTH	0.19	0.19	0.19	0.19	0.19	0.19	0.19
S.W.DEVON	0.34	0.34	0.34	0.34	0.34	0.34	0.34
ALLERS&	0.25	0.25	0.25	0.25	0.25	0.25	0.25
E.DEVON	0.26	0.26	0.27	0.26	0.27	0.27	0.27
TOTAL	0.27	0.27	0.27	0.27	0.27	0.27	0.27

TABLE B3 - HIGH DEMAND FORECASTS (Ml/D)

	1991	1996	2001	2006	2011	2016	2021
UNMEASURED TOURIST+MISC. (HIGH)							
COLLIFORD	4.94	5.53	6.14	6.75	7.39	8.05	8.73
N.DEVON	1.12	1.25	1.37	1.52	1.67	1.82	1.98
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	3.56	3.86	4.19	4.49	4.79	5.11	5.46
ALLERS&	0.53	0.56	0.60	0.63	0.67	0.71	0.75
E.DEVON	0.41	0.44	0.47	0.51	0.54	0.58	0.62
TOTAL	10.56	11.64	12.77	13.90	15.05	16.27	17.54
% UNMEASURED TOURIST+MISC. (HIGH)							
COLLIFORD	0.03	0.04	0.04	0.04	0.04	0.04	0.04
N.DEVON	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PLYMOUTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.W.DEVON	0.04	0.04	0.04	0.04	0.04	0.04	0.04
ALLERS&	0.01	0.01	0.01	0.01	0.01	0.01	0.01
E.DEVON	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	0.02	0.02	0.02	0.02	0.02	0.02	0.02
UNMEASURED DOMESTIC (HIGH)							
COLLIFORD	60.39	67.60	75.23	82.97	91.15	99.72	108.74
N.DEVON	25.02	27.48	30.07	33.28	36.48	39.99	43.69
PLYMOUTH	44.58	48.51	52.63	56.35	59.97	63.85	67.89
S.W.DEVON	39.22	43.04	47.06	50.75	54.39	58.31	62.79
ALLERS&	23.89	25.77	27.74	29.84	32.02	34.51	37.11
E.DEVON	15.32	16.72	18.20	19.82	21.34	23.12	24.98
TOTAL	208.42	229.12	250.93	273.00	295.35	319.51	345.19
% UNMEASURED DOMESTIC (HIGH)							
COLLIFORD	0.39	0.47	0.47	0.47	0.47	0.47	0.48
N.DEVON	0.34	0.41	0.41	0.41	0.41	0.41	0.42
PLYMOUTH	0.47	0.50	0.51	0.51	0.52	0.52	0.52
S.W.DEVON	0.42	0.49	0.50	0.50	0.51	0.51	0.51
ALLERS&	0.39	0.42	0.42	0.42	0.42	0.43	0.43
E.DEVON	0.40	0.46	0.47	0.47	0.48	0.48	0.49
TOTAL	0.40	0.46	0.47	0.47	0.47	0.47	0.48
LEAKAGE CONTROL (HIGH)							
COLLIFORD	42.62	20.26	22.04	24.25	26.53	28.89	31.32
N.DEVON	20.69	9.56	10.27	11.31	12.36	13.46	14.59
PLYMOUTH	20.43	18.20	18.73	19.88	21.02	22.23	23.50
S.W.DEVON	26.82	14.36	15.52	16.60	17.68	18.80	20.05
ALLERS&	17.10	14.19	15.18	16.22	17.27	18.43	19.61
E.DEVON	11.22	7.45	8.00	8.60	9.17	9.80	10.47
TOTAL	138.88	84.02	89.74	96.85	104.02	111.61	119.53
% LEAKAGE CONTROL (HIGH)							
COLLIFORD	0.28	0.14	0.14	0.14	0.14	0.14	0.14
N.DEVON	0.28	0.14	0.14	0.14	0.14	0.14	0.14
PLYMOUTH	0.22	0.19	0.18	0.18	0.18	0.18	0.18
S.W.DEVON	0.29	0.16	0.16	0.16	0.16	0.16	0.16
ALLERS&	0.28	0.23	0.23	0.23	0.23	0.23	0.23
E.DEVON	0.29	0.21	0.20	0.20	0.20	0.20	0.20
TOTAL	0.27	0.17	0.17	0.17	0.17	0.17	0.17

MEASURED (HIGH)							
COLLIFORD	36.68	40.81	44.94	49.07	53.19	57.32	61.45
N.DEVON	23.36	26.15	28.94	31.74	34.53	37.32	40.12
PLYMOUTH	23.12	24.04	24.99	25.97	26.98	28.02	29.10
S.W.DEVON	20.20	21.44	22.67	23.91	25.14	26.38	27.61
ALLERS&	17.29	18.63	19.96	21.30	22.63	23.97	25.31
E.DEVON	9.10	9.57	10.03	10.50	10.96	11.43	11.90
TOTAL	129.74	140.63	151.53	162.47	173.44	184.45	195.48

% MEASURED (HIGH)							
COLLIFORD	0.24	0.28	0.28	0.28	0.28	0.27	0.27
N.DEVON	0.32	0.39	0.39	0.39	0.39	0.38	0.38
PLYMOUTH	0.25	0.25	0.24	0.24	0.23	0.23	0.22
S.W.DEVON	0.22	0.25	0.24	0.24	0.23	0.23	0.23
ALLERS&	0.28	0.30	0.30	0.30	0.30	0.30	0.29
E.DEVON	0.24	0.26	0.26	0.25	0.25	0.24	0.23
TOTAL	0.25	0.28	0.28	0.28	0.28	0.27	0.27

UNMEASURED NON-DOMESTIC (HIGH)							
COLLIFORD	9.98	11.17	12.41	13.66	14.96	16.30	17.69
N.DEVON	2.69	2.99	3.30	3.65	4.00	4.37	4.74
PLYMOUTH	6.08	6.56	7.06	7.52	7.97	8.44	8.94
S.W.DEVON	4.02	4.37	4.73	5.07	5.41	5.77	6.17
ALLERS&	2.42	2.56	2.71	2.87	3.02	3.20	3.38
E.DEVON	2.02	2.18	2.35	2.53	2.70	2.90	3.10
TOTAL	27.21	29.83	32.56	35.30	38.06	40.98	44.01

% UNMEASURED NON-DOMESTIC (HIGH)							
COLLIFORD	0.06	0.08	0.08	0.08	0.08	0.08	0.08
N.DEVON	0.04	0.04	0.04	0.04	0.04	0.05	0.05
PLYMOUTH	0.06	0.07	0.07	0.07	0.07	0.07	0.07
S.W.DEVON	0.04	0.05	0.05	0.05	0.05	0.05	0.05
ALLERS&	0.04	0.04	0.04	0.04	0.04	0.04	0.04
E.DEVON	0.05	0.06	0.06	0.06	0.06	0.06	0.06
TOTAL	0.05	0.06	0.06	0.06	0.06	0.06	0.06

TOTAL WITH LEAKAGE CONTROL (HIGH)							
COLLIFORD	154.62	145.37	160.66	176.69	193.22	210.28	227.93
N.DEVON	72.88	67.44	73.96	81.49	89.03	96.95	105.10
PLYMOUTH	94.19	97.30	103.41	109.73	115.94	122.55	129.42
S.W.DEVON	93.81	87.06	94.17	100.82	107.41	114.37	122.08
ALLERS	61.23	61.72	66.18	70.85	75.62	80.83	86.16
E.DEVON	38.05	36.36	39.06	41.95	44.71	47.83	51.06
TOTAL	514.79	495.25	537.45	581.53	625.92	672.80	721.75
CHECK	514.79	495.24	537.54	581.53	625.92	672.81	721.76

LEAKAGE CONSTANT (HIGH)							
COLLIFORD	48.09	53.72	61.08	67.13	73.40	78.01	84.60
N.DEVON	23.15	25.65	28.22	31.09	33.96	36.98	40.07
PLYMOUTH	20.43	22.11	23.87	25.45	27.01	28.69	30.51
S.W.DEVON	39.36	42.69	46.16	49.37	52.56	55.91	59.61
ALLERS&	17.10	18.54	20.01	21.54	23.10	24.80	26.55
E.DEVON	11.22	12.08	12.98	13.94	14.87	15.91	16.99
TOTAL	159.34	174.79	192.32	208.51	224.89	240.29	258.32

TOTAL WITH LEAKAGE CONSTANT (HIGH)

COLLIFORD	160.08	178.83	199.71	219.57	240.09	259.40	281.21
N.DEVON	75.35	83.53	91.92	101.27	110.63	120.47	130.59
PLYMOUTH	94.19	101.21	108.55	115.29	121.93	129.00	136.43
S.W.DEVON	106.36	115.40	124.81	133.58	142.29	151.48	161.64
ALLERS&	61.23	66.06	71.01	76.17	81.44	87.19	93.10
E.DEVON	38.05	40.98	44.03	47.30	50.41	53.94	57.58
TOTAL	535.25	586.01	640.02	693.18	746.79	801.48	860.54

% LEAKAGE CONSTANT

COLLIFORD	0.30	0.30	0.31	0.31	0.31	0.30	0.30
N.DEVON	0.31	0.31	0.31	0.31	0.31	0.31	0.31
PLYMOUTH	0.22	0.22	0.22	0.22	0.22	0.22	0.22
S.W.DEVON	0.37	0.37	0.37	0.37	0.37	0.37	0.37
ALLERS&	0.28	0.28	0.28	0.28	0.28	0.28	0.29
E.DEVON	0.29	0.29	0.29	0.29	0.29	0.29	0.30
TOTAL	0.30	0.30	0.30	0.30	0.30	0.30	0.30

Evaluation of Strategic Supply Zone
Peaking Factors

As discussed in Section 2 of the Main Report, weekly demand data were provided by SWWSL for the old operational districts in the period between 1976 to 1990. These weekly demands were not broken down to show figures for individual WIS zones; only annual average demands were available for the latter.

A direct assessment of the annual demands in the new operational strategic supply zones was achieved by combining the figures for the constituent WIS zones. The lack of similar weekly demand data prevented the peak week and peak 4-week demands, and thereby peaking factors, being calculated in the same way.

Instead a more simple approach was used, which involved the combination and disengagement of the mean peaking factors calculated for the operational districts.

The adjustments are shown below in Table B4.

Table B4

Operational District	Peak Period Demand Factor (1976-1990 mean)	Comparable Strategic Supply Zone	Peak Period Demand Factor (calculated)
Fal	1.13	Colliford	1.15
Fowey	1.18		
Taw	1.10	Roadford ND & Plymouth	1.07
Tamar	1.06		
Dart	1.19	Roadford SW Devon	1.19
Exe	1.09	Allers & Pynes	1.06
		East Devon	1.15

The Colliford peak 4-week demand factor is a weighted average of the Fal and Fowey peaking factors, based upon the 1991 annual average demands in the two operational districts. The calculation is shown below.

	Fal	Fowey	Colliford
1991 Predicted annual average demand (Ml/d)	77.92	53.86	131.78
1976-1990 Mean peaking factor	1.13	1.18	$\frac{77.92 \times 1.13}{131.78} + \frac{53.86 \times 1.18}{131.78} = 1.15$

The same calculation has been performed in order to establish a peak demand factor for the combined Roadford N Devon and Plymouth strategic supply zone, using the Taw and Tamar data as a starting point.

	Taw	Tamar	Roadford - N Devon & Plymouth
1991 Predicted annual average demand (Ml/d)	54.49	121.09	175.58
1976-1990 Mean Peaking factor	1.10	1.06	$\frac{(54.49 \times 1.10)}{(175.58)} + \frac{(121.09 \times 1.06)}{(175.58)} = 1.07$

The Dart operational district is comparable with the new Roadford South West Devon strategic zone and therefore the same peaking factor has been assumed.

The old Exe operational district has been split up into the Allers & Pynes and East Devon strategic supply zones. A simple method of establishing a peaking factor for the new zones would have been to ascribe the peaking factor of the Exe district (1.09) to both areas. However, using this method, no distinction would be made between the pattern of consumption of Aller & Pynes, with a high urban population, and East Devon, where tourism is an important local industry.

Additional information was required in order to distinguish the peak demand patterns in the two strategic zones. This was obtained from SWWSL's 'Exe District Strategy Review Report to the NRA' produced in 1991. In Appendix B of that Report, average and peak week demands were given for the WIS zones in the Exe region, for the years 1986-1988 inclusive.

The average peaking factors over the three years were evaluated for each WIS zone and then the zones were combined using the same method as described previously, to establish peak week demand factors for Allers & Pynes & East Devon.

<u>Peak Week : Annual Average Demand Ratios 1986 - 1988</u>

Allers & Pynes	1.08	
East Devon	1.21	
Exe Region	1.13	(mean of ratios recorded during 1986, 1987 & 1988)

These figures are peak week rather than peak 4-week, and are correspondingly higher. The figures provide a ratio by which the overall peaking factor of the Exe can be divided. There are two methods by which the 4 week peak demand ratio can be derived from the peak week demand ratio; either method can be assumed to be valid in the context of this Report.

Method 1

The ratio of the mean peak week: 4 week peak demand for Exe district during 1986 to 1988 is determined

$$\frac{\text{P W Ratio}}{\text{P 4W Ratio}} \quad \frac{1.13}{1.09} = 1.04$$

This new ratio is then to be applied to Allers and Pynes and East Devon to establish new peak 4 week factors.

$$\text{Allers \& Pynes} \quad \frac{1.08}{1.04} = 1.04$$

$$\text{East Devon} \quad \frac{1.21}{1.04} = 1.167$$

The Exe district 1991 annual average demand is divided between A&P and ED in the proportion 61%:39%. Thus the peaking factor calculation can be checked using the following equation:

$$(0.39 \times 1.167) + (0.61 \times 1.04) = 1.09$$

Method 2

The ratio of the incremental demand increases during the peak week and 4 week peak periods is determined.

$$\frac{\text{\% Increase in demand during a peak week}}{\text{\% Increase in demand during a peak 4 week}}$$

$$= \frac{13}{9} = 1.444$$

This new ratio is then applied to Aller & Pynes and East Devon to establish new 4 week peak factors

$$\text{Allers \& Pynes} = \frac{0.08}{1.444} = 0.055$$

$$\text{E Devon} = \frac{0.21}{1.444} = 0.145$$

These figures translate to 4 week peaking factors of

A&P = 1.06
ED = 1.15

Using the check equation

$$(0.39 \times 1.145) + (0.61 \times 1.055) = 1.09$$

For the purposes of this report method 2 has been adopted, since it gives a more conservative range of peaking factors, (ie higher factors for E Devon) although it is understood that this method is probably not the most statistically robust.

Thus the new peak 4-week ratios based on the Exe fifteen year average peaking factor are:

Allers & Pynes	1.06
East Devon	1.15
Exe	1.09

In carrying out this calculation, it has been assumed that the sum of demand of the part is equal to the demand of the whole Exe region. In practice this is not the case; the summation of peak demands in the parts is likely to be higher than that in the whole, because the peaks do not occur concurrently. Without more data, an evaluation of the increase in peaking factors of E Devon & Allers & Pynes due to the above phenomena would have to be purely subjective. It was therefore agreed to use the peaking factors of 1.15 and 1.06 respectively for East Devon and for Allers and Pynes, in the analysis presented in this Report.

Appendix C

PRIVATE ABSTRACTION LICENCED DAILY ENTITLEMENTS

HALCROW

APPENDIX C - PRIVATE ABSTRACTION AUTHORISED QUANTITIES

PRIVATE ABSTRACTION ENTITLEMENTS

ABBREVIATIONS

SP	Spray Irrigation	-	Agricultural
		-	Municipal
AGR	Agriculture	-	General use (excluding fish farming)
IND-P	Industrial Processing	-	Power industry (boiler feed)
		-	Quarrying
		-	Food & Drink
		-	Miscellaneous
G.W	Ground Water abstraction		
S.W	Surface Water abstraction		

Abstractions for fish farming and hydro power generation are not included in the following tables.

TABLE C1 East Devon Strategic Supply Zone Abstractions

River Catchment			Abstraction Purpose		
			SP (Ml/d)	AGR (Ml/d)	IND-P (Ml/d)
Axe	-	G.W	0.55	3.58	0.20
& Yarty	-	S.W	7.08	0.05	10.22
Otter	-	G.W	1.45	1.71	0.01
	-	S.W	4.18	0.02	0
Lim	-	G.W	0	0.43	0.08
& Sid	-	S.W	0	0	0.06
TOTALS			13.3	5.8	10.6
			29.7		

TABLE C2 Allers & Pynes Strategic Supply Zone Abstractions

River Catchment			Abstraction Purpose		
			SP (Ml/d)	AGR (Ml/d)	IND-P (Ml/d)
Exe	-	G.W	12.02	9.38	4.63
	-	S.W	22.71	0.08	15.95
TOTALS			34.7	9.5	20.6
			64.8		

TABLE C3 Roadford South West Devon Strategic Supply Zone Private Abstractions

River Catchment			Abstraction Purpose		
			SP (Ml/d)	AGR (Ml/d)	IND-P (Ml/d)
Teign	-	G.W	0.77	2.21	1.77
	-	S.W		DATA	UNAVAILABLE
Dart	-	G.W	0.69	2.55	0.50
	-	S.W	1.42	0.07	2.46
Avon	-	G.W	0	0.30	0
	-	S.W	3.06	0	0
TOTALS			5.9	5.1	4.7
			15.8		

TABLE C4 Roadford North Devon and Plymouth Strategic Supply Zone Private Abstractions

River Catchment		Abstraction Purpose		
		SP (Ml/d)	AGR (Ml/d)	IND-P (Ml/d)
Erme -	G.W	0.01	0.35	0
-	S.W	1.15	0	1.59
Yealm -	G.W	0	0.21	3.66
-	S.W	0.36	0	2.70
Plym -	G.W	0.02	0.08	12.91
-	S.W	0.02	0.01	27.69
Tamar -	G.W	1.29	2.65	0.74
(incl R. Lynher)	S.W	4.15	0.02	2.47
Torridge -	G.W	0.07	0.31	0
-	S.W	0.10	0	1.60
Hartland/-	G.W	0	0	0
Clovelly -	S.W	0	0	0.01
Taw -	G.W	0.35	2.00	1.59
-	S.W	0.03	0.02	2.97
North -	G.W	0	0.15	0
Devon -	S.W	0.33	0	0
Streams				
East & -	G.W	0	0	0
West -	S.W	0.06	0	0.11
Lyn				
TOTALS		7.9	5.8	58.0
		71.7		

TABLE C5 Colliford Strategic Supply Zone Private Abstractions

River Catchment		Abstraction Purpose		
		SP (Ml/d)	AGR (Ml/d)	IND-P (Ml/d)
East & West Looe -	G.W	1.58	0.31	0.01
-	S.W	0.29	0.03	0
Fowey -	G.W	0.31	0.56	0
	S.W	0.55	0.04	0.02
Fal -	G.W	0.85	1.75	22.29
	S.W	1.79	0	19.96
Halye -	G.W	3.00	0.45	1.78
	S.W	6.42	0.02	0.02
Red River -	G.W	1.52	0.33	0
-	S.W	0.39	0	1.31
Camel -	G.W	0.03	0.93	0
-	S.W	1.97	0	0.27
Cober -	G.W	0	0.21	0
-	S.W	0.73	0.01	0.02
Par -	G.W	0	0.11	14.54
-	S.W	0.09	0	0.81
St Austell -	G.W	0.09	0.18	39.37
-	S.W	0	0.01	0.33
South Coast Streams -	G.W	0.90	0.46	1.33
-	S.W	2.56	0.04	0
Miscellaneous				
-	G.W	0.33	0.85	5.79
-	S.W	0.22	0	0.20
TOTALS		23.6	6.3	108.1
		138.0		

Appendix D

PEAK PERIOD DROUGHT RELIABLE YIELDS FOR SWWSL SUPPLY AREA

HALCROW

APPENDIX D

Licence and Yield Estimate Details by Operational District

Revised October 1991

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Colliford	Drift reservoir	24/S	31	10.91	10.90	10.90
Colliford	Polteggan well	24/G	75	0.62	0.00	0.00
Colliford	Fortescue shaft	26/G	201	1.92	0.00	0.00
Colliford	Argal+College reservoirs	231/S	14	9.55	9.10	9.10
Colliford	River Cober (Wendron)	232/S	14	8.22	0.00	0.00
Colliford	River Hayle	252/S	22	4.26	0.00	0.00
Colliford	Stithians reservoir	22/S	23	28.27]	20.90	20.90
Colliford	Kennal vale	22/S	29	11.21]		
Colliford	Cargenwyn res (stream+springs)	26/S	35	1.25)	2.10	2.10
Colliford	Carwynnen stream	26/S	45	1.64)		
Colliford	Roseworthy stream	26/S	55	3.25)		
Colliford	Boswyn stream	26/S	57	1.87)		
Colliford	Boswyn shaft+Cooper Hill adit	26/G	189	1.87)		
TOTAL				84.84		43.00

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Colliford	River Porth and Porth Reservoir	272/S	9	6.30	No Data	6.30
Colliford	Trewollack mineshaft	272/G	50	0.62	0.00	0.00
Colliford	Crowdy reservoir	281/S	23	6.04	6.20	6.20
Colliford	River Fowy at Trekelvesteps	18/S	32	15.91)	139.00	139.00
Colliford	Colliford lake	18/S	35	14.77)		
Colliford	River Fowey, Restormel	18/S	40	79.18)		
Colliford	De Lank river	283/S	3	8.77	0.00	0.00
Colliford	Siblyback reservoir	18/S	34	3.01]		
Colliford	Withybrook, Bastreet	141/S	26	9.09]	9.10	9.10
TOTAL				228.53		203.60

APPENDIX D continued

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Roadford N Devon & Plymouth	Gammaton reservoir	07	0135	0.75	0.50	0.50
Roadford N Devon & Plymouth	Red-a-ven/Black-a-ven	07	0136	1.14	0.90	0.90
Roadford N Devon & Plymouth	Melbury reservoir	07	0141	1.49	1.40	1.40
Roadford N Devon & Plymouth	West Okement/Meldon reservoir	07	0167	27.28	21.20	21.20
Roadford N Devon & Plymouth	River Torridge	07	0173	6.82	4.60	4.60
Roadford N Devon & Plymouth	Holywell reservoir	08	0535	1.00	0.50	0.50
Roadford N Devon & Plymouth	Taw Marsh boreholes	08	0563	7.47	0.00	0.00
Roadford N Devon & Plymouth	River Taw, Newbridge	08	0713	14.79	0.00	0.00
Roadford N Devon & Plymouth	Spreycott stream	08	0725	0.91	0.00	0.00
Roadford N Devon & Plymouth	West Ilkerton river	09	0056	1.10	NO DATA	1.10
Roadford N Devon & Plymouth	Slade reservoir	09	0057	1.49	1.60	1.60
Roadford N Devon & Plymouth	Jennetts reservoir	07	0186	1.87)	2.20	2.20
Roadford N Devon & Plymouth	River Yeo	07	0187	1.25)		
Roadford N Devon & Plymouth	River Yeo, Loxhore	08	0536	6.23]	6.40	6.40
Roadford N Devon & Plymouth	Bratton stream	08	0670	4.55]		
Roadford N Devon & Plymouth	River Bray, Leehamford	08	0694	11.02)	11.10	11.10
Roadford N Devon & Plymouth	Wistlandpound reservoir	08	0695	12.45)		
Roadford N Devon & Plymouth	Brockenburrow intake	08	0696	0.95)		
TOTAL				102.56		51.5

APPENDIX D continued

Strategic District	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Roadford N Devon & Plymouth	Upper Tamar lake	8/S	2	6.29	8.20	8.20
Roadford N Devon & Plymouth	Wheal Lucky adit+springs	42/G	14	0.34	0.10	0.10
Roadford N Devon & Plymouth	Burrator reservoir	2/S	31	80.96)		
Roadford N Devon & Plymouth	Devonport leat, Dousland intake	2/S	32	22.42)		
Roadford N Devon & Plymouth	River Meavy, Stanlake intake	2/S	33	9.09)		
Roadford N Devon & Plymouth	Devonport leat	04	0555	0.01)	197.00	197.00
Roadford N Devon & Plymouth	W.Dart/Cowsic/Blackbrook-drain to Devonport Leat	04	0558	23.66)		
Roadford N Devon & Plymouth	River Tamar, Gunnislake	13/S	20	148.00)		
Roadford N Devon & Plymouth	River Tavy, Lopwell	41/S	39	91.00)		
Roadford N Devon & Plymouth	Roadford reservoir	52/S	6	81.50)		
Roadford N Devon & Plymouth	R.Yealm/Broadall lake/Ford brook	1/S	25	3.11]		
Roadford N Devon & Plymouth	Erme intake/Red lake/Left lake	06	0074	6.85]	3.00	3.00
Roadford N Devon & Plymouth	Butterbrook reservoir	06	0075	0.50]		
TOTAL				576.29		259.8

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Roadford S.W. Devon	Chagford springs	03	0599	0.15	0.10	0.10
Roadford S.W. Devon	Mylor borehole	03	0605	0.25	NO DATA	0.25
Roadford S.W. Devon	Brixham spring	03	0762	0.37	0.50	0.50
Roadford S.W. Devon	Halsanger springs	04	0541	0.19	0.50	0.50
Roadford S.W. Devon	Old mill reservoir, Dartmouth	04	0542	0.62	1.10	1.10
Roadford S.W. Devon	Brockhill Mire + Lambsdown springs	04	0546	0.19	0.00	0.00
Roadford S.W. Devon	Littlehempston rad collector + bh's	04	0572	16.25	15.90	15.90
Roadford S.W. Devon	River Dart	04	0586	25.78	9.00	9.00
Roadford S.W. Devon	Thorns intake	02	1921	1.49}	3.00	3.00
Roadford S.W. Devon	Duckaller borehole (+ compen.bh)	02	2139	3.81}		
Roadford S.W. Devon	Vennbridge borehole (+ compen.bh)	02	2301	2.50}		
Roadford S.W. Devon	Fernworthy reservoir	03	0614	14.95)	23.90	23.90
Roadford S.W. Devon	Kennick, Tottiford + Trenchford res	03	0615	16.19)		
Roadford S.W. Devon	Swincombe intake	04	0651	11.83]	8.20	8.20
Roadford S.W. Devon	Venford reservoir	04	0652	6.85]		
Roadford S.W. Devon	Avon reservoir	05	0114	13.70)	9.30	9.30
Roadford S.W. Devon	Bala brook intake	05	0115	1.12)		
TOTAL				116.24		71.75

APPENDIX D continued

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
Allers & Pynes	River Exe, North Bridge intake	02	1861	24.46]	75.20	75.20
Allers & Pynes	River Exe, North Bridge	02	2019	39.18]		
Allers & Pynes	Bolham leat	02	2336	32.00]		
Allers & Pynes	Pynes leat	02	2101	29.00]		
Allers & Pynes	Aller springs	02	0083	0.93	0.20	0.20
Allers & Pynes	Brampford Speke borehole	02	1825	3.54	0.00	0.00
Allers & Pynes	Stoke Canon borehole	02	1863	1.70	0.00	0.00
Allers & Pynes	Sheldon springs	02	1881	1.37	0.50	0.50
Allers & Pynes	Uton borehole	02	1894	0.93	0.60	0.60
Allers & Pynes	Coleford borehole	02	2314	0.78	0.00	0.00
Allers & Pynes	Knowle borehole	02	2332	0.34	1.0	1.00
Allers & Pynes	Clannaborough Adit	08	0537	0.68	0.4	0.40
TOTAL				134.91		77.9

APPENDIX D continued

Strategic Zone	Name	Licence Number		Annual Licensed Ml/d	SWWSL DRY Ml/d	Assumed drought reliable yield Ml/d
East Devon	Greatwell 4b borehole	01	0414	1.69]	8.50	8.50
East Devon	Greatwell boreholes	01	0426	4.36]		
East Devon	Greatwell no 5 borehole	01	0505	2.49]		
East Devon	Colaton Raleigh boreholes 2 & 4	01	0478	2.59)	12.60	12.60
East Devon	Harpford boreholes	01	0518	7.60)		
East Devon	Dotton boreholes	01	0519	10.73)		
East Devon	Dotton boreholes	01	0520	4.36)		
East Devon	Wilmington springs	00	0669	2.33	1.10	1.10
East Devon	Hook springs + Cotley springs	00	0676	1.73	0.80	0.80
East Devon	Couchill springs	00	0677	0.75	0.30	0.30
East Devon	Holyford ponds	00	0678	1.15	0.90	0.90
East Devon	Bovey Lane boreholes	00	0679	0.55	0.50	0.50
East Devon	Pinhay springs	00	0790	3.41	2.10	2.10
East Devon	River Axe, Whitford bridge	00	0835	4.50	0.00	0.00
East Devon	St Cyres spring	01	0417	0.45	0.20	0.20
East Devon	Sidford 3 borehole	01	0418	2.00	0.00	0.00
East Devon	Kersbrook springs	01	0425	2.18	1.00	1.00
East Devon	A Squabmoor res + Yettington intakes	01	0422	2.27)	0.90	0.90
East Devon	A Budleigh brook	01	0494	1.37)		
East Devon	Otterton 1a and 4 boreholes	01	0544	6.34	3.00	3.00
TOTAL				62.85		31.90