National Rivers Authority

WATER RESOURCE PLANNING - STRATEGIC OPTIONS

Preliminary Report

May 1991

HALCROW

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Sir William Halcrow & Partners Ltd Burderop Park Swindon Wiltshire
SN4 0QD UK Tel 0793 812479 Telex 44844 Halwil G Fax 0793 812089

HALCROW
Consulting Engineers

Sir William Halcrow & Partners Ltd
Burderop Park, Swindon,
Wiltshire SN4 0QD, England
Telephone 0793 812479
International Telephone + 44 793 812479
Telex 44844 Halwil G
Fax 0793 812089
International Fax +44 793 812089
And at
Vineyard House, 44 Brook Green,
London W6 7BY, England.
Telephone 071-602 7282.

National Rivers Authority
Suite 39
Aztec Centre
Aztec West
Almondsbury
Bristol BS12 4TD

For the attention of Mr J Sherriff

31 May 1991 Our ref WMG/WRP 17/024 Your ref

Dear Sirs

WATER RESOURCES PLANNING - STRATEGIC OPTIONS

In accordance with the Brief for the above project, we have pleasure in enclosing 15 copies of our Preliminary Report. The document addresses scope for further ground and surface water resources, and the findings to date of our review of strategic options.

We understand that you intend to circulate copies to the 10 NRA regions, and would ask that you request them to review the report and comment back to you upon it at an early date, so that their views can be incorporated as the study proceeds.

We look forward to seeing you at the Progress Meeting here at 2.00 p.m. on 5 June. If you have any queries in the meantime, please do not hesitate to contact either myself or Patrick Hawker at this office.

Yours faithfully

J D LAWSON

Encl.

WATER RESOURCES PLANNING - STRATEGIC OPTIONS

PRELIMINARY REPORT

CONTENTS

TABLES

FIGURES

1 INTRODUCTION AND SUMMARY

1.1 Introduction

This Preliminary Report is the second document prepared by Halcrow in the course of the water resource strategy study with which we are assisting the National Rivers Authority (NRA). Work on the project continues towards production of a Drat Final Report at the end of July, and findings presented in this document are subject to review as studies proceed.

The Preliminary Report considers the scope for further development of ground and surface water resources in England and Wales, within the constraints of current levels of use, environmental impact and water quality. Progress to date on the review of strategic options is also described.

1.2 Summary

The current and planned level of groundwater development in England and Wales means that little or no unused resources of significance in strategic terms remain. In fact, adverse impacts associated with groundwater sources in some areas suggest that a reduction in abstraction - at least for direct supply use - is desirable. River augmentation schemes are potentially less damaging but require sensitive planning and operation.

Although there are some quality problems associated with groundwater, they tend to be localised in effect and are of negligible significance in strategic terms.

Insofar as obtaining increased yields from groundwater sources is possible, the best hope would seem to be through river augmentation, possibly by remodelling some direct supply schemes to operate in this way. However, bearing in mind the significant level of conjunctive use which already occurs, and the need for abstraction cut-backs in some areas, it is thought that the likely gain beyond what can be achieved through existing and planned schemes will not be significant in strategic terms.

Further development of surface resources is altogether more promising in the West and North, with Welsh and North West Regions apparently having most available water, and Anglia and Thames least. For environmental and operational reasons, further development should preferably involve storage; there are opportunities to enhance the yields of some existing schemes through pumped augmentation of reservoirs.

Surface water quality overall is not a constraint, especially when the current programme of sewage treatment works improvements is borne in mind. However, there are some significant problems in the Mersey catchment, and locally in parts of Severn Trent region. Also of some concern are the implications of exotic pollutants in rivers carrying effluents from major inland industrial conurbations, such as the Trent below Birmingham.

Strategic options entailing demand management, effluent re-use and inter-regional transfers all merit further consideration. Water grids are seen as a more localised solution to provide operational flexibility.

Transfer of fresh water by sea does not appear promising, although some further work is needed to confirm this in the case of moving water round the coast in supertankers.

2 GROUNDWATER RESOURCE DEVELOPMENT

2.1 Existing Commitment and Planned Schemes

The importance of groundwater to meeting demands in England and Wales is clearly indicated by the available data. Some 31% of the public water supply, representing about 6400 Ml/d, originates directly from groundwater.

The individual reliance of each region on groundwater supply is given in Figure 1. It is apparent that for most regions to the south and east of England, the dependence on groundwater is higher than 40%, with Southern Region meeting 74% of local demands through groundwater.

The most important aquifers are the Chalk and the Permo-Triassic (Sherwood) Sandstones which together provide up to 70% of the total groundwater output in England and Wales.

Table 1 includes estimates of the available resource by region, expressed in terms of the recharge. It must be recognised that this figure is an indication of the resource levels only, and takes no account of the factors implicit in a safe yield approach to aquifer management, such as baseflow regulation and groundwater quality protection, or of the fact that the distribution of groundwater can be highly varied both spatially and temporally.

Table 2 summarises the available data for groundwater use by region, in terms of the contribution of the major aquifer units to local supply.

As data collection and analytical techniques have improved in recent years, so it has been possible to determine aquifer yields more reliably. In general, much of the available groundwater has been committed to supply, although there are several new schemes planned to meet anticipated demand increases over the next two to three decades. Generally, these fall into 3 types:

- small scale direct supply schemes to satisfy demands in rural areas where settlements are relatively small and far apart;
- larger direct supply schemes from wellfields developed close to the middle or lower reaches of major rivers;
- river augmentation schemes.

The first type is exemplified by the proposed further development of the chalk aquifer for local needs in North Yorkshire. Examples of the second and third types include the continuing development of the Gatehampton Scheme (Thames Region) and the Shropshire Groundwater Scheme (Severn-Trent Region) respectively.

Table 3 gives a breakdown of the yields of the planned groundwater schemes identified in the NRA Section 143 Report (March 1991) according to the three categories identified above. It may be seen that:

- planned schemes account for a further 1136 Ml/d of groundwater development;
- of this, the greatest proportion (47%) relates to river augmentation schemes;
- of the direct abstraction schemes, 20% relate to the middle and lower catchments of major rivers, and 33% to local schemes.

The overall increase of 1136 Ml/d for public supply related groundwater abstractions represents 18% of the current comparable figure of 6412 Ml/d (1987 data).

It is concluded that groundwater development trends are moving away from significant direct abstractions in headwater areas and next to minor streams. This trend is undoubtedly driven by the increased awareness of low flow problems associated with groundwater abstraction.

2.2 Constraints

2.2.1 Environmental Implications

The potential for further groundwater development in England and Wales would appear to be severely limited by environmental considerations. Indeed, it appears that a significant proportion of existing groundwater abstractions are having an environmental impact that is considered by many to be unacceptable. It is suggested that a number of existing abstractions will be stopped or reduced in the foreseeable future.

Abstraction of groundwater, especially remote from a stream, appears at first sight an elegant water resource development producing high quality water that requires minimal treatment. However, an increasing understanding of the dynamics of the groundwater fed stream environment has led to the realisation that any sizeable abstraction is likely to have some impact. Impacts involve:

- local lowering of the water table causing streams to dry up;
- local lowering of the water table causing wetlands to dry out;
- reduced spring flows and thus reduced stream flow at various seasons;
- delay in winterbourne breakthrough;
- compounding effect over several dry years eg 1988-1991.

The subtlety of the impact of seasonally reduced flows has only recently started to be properly understood. Increased winter flows appear to be critical in terms of stream sediment dynamics, calling into serious doubt the idea that winter recharge of a depleted aquifer, at the expense of high water flows, is a benign impact. The possibility that sediment transport is reduced due to a lack of winter high flows on the River Test is being examined by Southern Region.

Resource managers in the five regions that licence the greatest extent of groundwater abstraction (Southern, Wessex, Thames, Anglian and Severn Trent - responsible between them for nearly 84% of groundwater abstractions) all consider the potential for further development to be strictly limited. All five regions have groundwater-fed streams in the NRA list of rivers with depleted flows and all have plans for some reductions. There is also the general view that the problems are much more widespread than the depleted riverflow listings, and that much greater reduction may be considered desirable or necessary in the foreseeable future. It is suggested that overall there is likely to be nett reduction in groundwater abstractions over the next decade or two. The resource implications of such reductions are significant.

Options which exist for amelioration of existing impacts include:

- shutting-down or reduction of abstraction;
- effluent return to the stream upstream of the cone of depression of the abstraction;
- re-siting boreholes in the lowermost areas of the catchment or in the coastal zone, returning effluents upstream;
- limit groundwater abstractions to times when surface-water takes are precluded by prescribed flows (ie, conjunctive use);
- aquifer recharge.

2.2.2 Water Quality

In a 1988 report on Assessment of Groundwater Quality in England and Wales (HMSO, 1988), it was concluded that:

'Although a number of potentially serious problems have been identified, the quality of groundwater used in public supply in England and Wales would appear to be good. We continue to be approximately 30% reliant on groundwater for public supply and there is currently no evidence of this reliance diminishing significantly as a result of quality deterioration.'

In work carried out for this Study, we have found no evidence that this situation has changed to any significant extent. Indeed, work is continuing to improve groundwater quality and reduce the threat. Establishment of a national groundwater quality monitoring network is understood to be underway through WRc Medmenham, while the NRA themselves are setting up a national aquifer protection policy, based on vulnerability to pollution. The establishment of nitrate sensitive areas is another positive step forward in groundwater protection.

Given the increased awareness of the threat to groundwater quality and greater understanding of the controls and processes involved, it is probable that the threat is reducing. However there is no room for complacency and the situation regarding many troublesome substances, particularly pesticides, is not yet fully documented. Also there is a general move through European Community (EC) legislation for tightening of water quality standards and a lowering of, for example, the Maximum Advisable Concentration (MAC) for nitrate, would have very serious consequences for groundwater sources which are currently marginal.

Nitrates and pesticides are examples of pollution from diffuse sources which are generally associated with agricultural activity, although non-agricultural use of pesticides is significant. Conversely, landfill (waste disposal) sites are an example of point source pollution (that is a discrete entity, from which contamination emanates). Collectively, nitrates, pesticides and pollution from waste disposal are currently regarded as the major threats to groundwater quality, although there are very few examples of sources having been lost due to landfill sites.

The nitrate problem has been extensively studied and reported upon in the last 20 years. Regular monitoring of groundwater shows a steadily rising trend in nitrate concentration which is regarded as mainly being attributable to use of fertilisers. It is a long-term problem with current concentrations often being attributable to farming activities many years ago. Where nitrate levels have been monitored over an extended period, a steadily rising trend is seen which in many cases will take nitrate concentration over the MAC level in the next 10-15 years. Some groundwater sources will inevitably be lost unless there is a possibility of blending. Treatment for nitrate is expensive and leads to the production of residues which are difficult to dispose of.

The situation on pesticides is less well understood. The compounds are persistent and difficult and expensive sample and analyse for. With current MAC levels in drinking water of not more than 0.1 μg/l of any single pesticide, and not more than 0.5 μg/l in total - regarded by many members of the water industry as 'surrogate zeros' - the pesticide problem must be regarded as serious. Although the majority of pesticide use is for agricultural purposes, the widespread use of organochlorine type weedkillers by the general public is probably significant in the face of such low MAC standards.

There are numerous other threats to groundwater quality from a wide variety of activities. Use of chlorinated solvents, which also have low MAC levels, is a significant problem in parts of the West Midlands. Similarly loads drainage to soakaways is a potential problem in many parts of south east England given the many miles of motorway which cross major aquifers and the risk of spillage of toxic chemicals. By comparison, the traditional threat to groundwater quality - saline intrusion - is largely under control. Although these other sources of pollution may be locally troublesome, nitrate, pesticides and to some extent waste disposal, remain the most significant long-term threats.

2.3 Opportunities

2.3.1 Further Direct Supply Schemes

Groundwater exploitation remains an efficient way of providing water, subject to environmental and quality constraints. It is likely therefore to remain an option against which alternatives are judged, both for localised supplies in rural areas, and where conditions permit more substantial abstractions without adverse impact - ie, near the middle and lower reaches of major rivers. However, in the case of the former it may well be necessary to provide compensation flow to nearby streams as an integral part of the development. In the case of abstractions associated with major rivers, the opportunities beyond those encompassed in schemes which are already planned are believed to be few.

In resource terms within the context of the strategic study, therefore, further opportunities beyond what is already planned are believed not to be significant. Conversely, however, there is a real likelihood that direct supply groundwater abstractions may have to be cut back to well below their current levels because of related low flow problems (see Section 2.2.1). This issue is being considered further as the study proceeds.

2.3.2 Further Augmentation Schemes

Groundwater augmentation schemes are less likely to cause low flow problems than direct supply schemes but, as noted in Section 2.2.1, are by no means free of potentially damaging impacts. In the trend towards ever more regulation of river flow, augmentation using groundwater is potentially important. However, the extent of further development of this type already planned (Table 3), coupled with increasing resistance by the public to further wholesale groundwater abstraction, suggest that there is little scope for this type of scheme in the longer term.

2.3.3 Modifications to Existing Schemes

With much of the reliable groundwater yield of England and Wales either fully committed or destined to become so, it is necessary to review options that may be possible within existing supply frameworks for enhancing aquifer output. The possible options to be considered include:

- use of additional resources resulting from 'rising' groundwater levels, notably in London and Birmingham

- redistribution of abstraction

- switch from direct abstraction to river regulation
- use of artificial recharge

The potential of using resource available through 'rising' groundwater levels is not promising. Because they occur in areas where there has been a steady decline in industrial groundwater abstraction, they are generally of poor quality. In the London Basin, 'rising' groundwater is associated with high salinity in areas immediately adjacent to the River Thames where prolonged industrial abstraction induced inflow at sites where the chalk aquifer was in hydraulic contact with the river. The result is that any additional groundwater is saline. It is also difficult to abstract, because it is highly localised and often beneath intensively developed land. In the case of 'rising' groundwater in the Birmingham area, there are water quality problems related to the industries active in the area until the late 1970's, including heavy metal and solvent contamination.

Redistribution of abstraction offers some relief in areas where groundwater yields are threatened by long-term contamination. For example the Northern and Southern chalk aquifer in the NRA Anglian region was developed - for sound historical reasons - in a manner that has left the abstraction system out of harmony with the resource. That is to say that much of the abstraction is concentrated around Grimsby, presenting a potential threat during drought periods of inducing saline intrusion from the Humber Estuary. Through the use of careful abstraction redistribution within the existing supply network, it has been possible for local industrial users and Anglian Water Services to cooperate with the NRA to reduce this threat of contamination. Techniques such as digital modelling as well as more efficient data collection made possible through computer usage afford far greater flexibility for managing groundwater resources.

Switching the operating regime of existing groundwater schemes from direct abstraction to river regulation would require the rezoning of distribution systems, and construction of river abstraction and treatment facilities some distance downstream. Besides this considerable expense, relatively few schemes would be suited to such a change. In many cases, new boreholes would be needed, as existing ones may be poorly sited to achieve sufficient net gain. In other cases, the present direct supply groundwater scheme may already be operated conjunctively with a surface-derived source, so that the marginal benefit of any switch to river regulation would be slight.

Whilst it is acknowledged that in certain circumstances increased yields could be obtained, and environmental impact reduced, by switching direct supply groundwater schemes to river regulation, it is considered that, in strategic terms, the benefit would be more than cancelled out by the desirable level of cutting back of abstraction from many groundwater schemes because of induced low flow problems.

The use of artificial recharge has a long history in London, where it was first attempted at the end of the nineteenth century. As a result of prolonged abstraction in the Central London area (between 1850 and 1940), groundwater levels were drawn down by as much as 80m. A large void remains and in some areas it is an attractive option to use this underground storage capacity to store surplus mains water for contingencies. The schemes are cost effective - in many cases much of the infrastructure including most of the wells necessary for recharge or abstraction are already in place.

A prototype scheme in the Lee Valley, incorporating 12 boreholes, which became operational in 1977 has demonstrated that large-scale artificial recharge of the multiple aquifer system in the London Basin is possible. Early reviews of the scheme indicated minor problems associated with water quality as a result of artificial recharge. However it was anticipated that these problems would become insignificant in the long-term. The Enfield-Haringey artificial recharge scheme is planned for development in an adjacent area to the Lee Valley site, and is likely to increase output from this area to 90 Ml/d. A further scheme is possible in South London which could increase supply by an additional 90 Ml/d.

2.3.4 Summary of Opportunities for Further Groundwater Development

It is concluded that, in strategic terms, there is virtually no scope for significant further groundwater development beyond the schemes already planned. Indeed, when environmental arguments are considered, there may need to be a net reduction in groundwater abstraction in the longer term, and resource planning models should test the implications of such an outcome.

3 SURFACE WATER RESOURCE DEVELOPMENT

3.1 Existing Commitments

Surface water resources can be defined as the water available for abstraction from rivers and lakes. The water can be abstracted by a wide variety of engineering schemes. These include direct river abstractions, direct supply reservoirs, river regulating reservoirs and pumped storage reservoirs. Supply systems usually consist of complex combinations of such schemes, often in conjunction with the use of groundwater resources. However, although the means of exploitation may be complex, the resource itself is simply the rain which falls on the land.

Not all of the rain which falls is available for abstraction. Some is consumed by vegetation and lost through evaporation. There is also a need for some water to be left to flow in rivers and discharge to the sea. This concept was recognised by the requirement for "minimum acceptable flows" (MAF) set out in the 1963 Water Act and retained in the 1989 Water Act.

The total water resource can be calculated using simple water balance equations:

Total water resource = rainfall - evaporation - MAF
Available water resource = total water resource - present net abstractions

This water balance approach is being used to give an indication of the extent of the existing exploitation of surface water resources and the potential for future development. Although simple in essence, the calculation is complicated by a number of factors:

i) **The reliability of rainfall.** Water supplies must be maintained during droughts and the long term average rainfall cannot be relied upon. To some extent this problem can be offset by the provision of water storage. For the purpose of this water balance, it has been assumed that the reliable rainfall is the one in ten year drought rainfall (annual rainfall with a probability of exceedance of 90%).

ii) **Calculation of minimum acceptable flow.** The MAF should ideally be determined for each river, taking into account the needs of water quality, fisheries, navigation and other environmental factors. Alternatively, the MAF can be taken arbitratarily as, for example, one eighth of the average daily flow in the river or the Q95 (flow exceeds for 95% of the time). For the purpose of simplicity in this water balance, the MAF has been taken as one-eighth of the average daily flow.

iii) **Evaporation.** The allowance for evaporation in the water balance should take into account the higher evaporation which takes place in droughts. For the purpose of the water balance evaporation has been taken as the mean annual evaporation, plus 20%.

iv) **Inter-catchment transfers.** If the water balances are being undertaken for defined regions or catchment areas, allowance has to be made for water entering or leaving through inter-catchment transfer schemes.

To calculate the available water resource, the existing abstractions have to be subtracted from the total water resource. The existing abstractions can be taken as the sum of the demands for public water supplies, industry and agriculture. They will include both surface and groundwater sources; inclusion of the latter in the water balance is correct, provided that long term mining of water is not taking place.

The re-use of water returned to rivers through sewage treatment works also needs to be taken into account. This can be obtained from available records of discharges from sewage works whose outfalls are located upstream of existing water supply abstractions.

The results of a preliminary water balance calculation for the ten NRA regions in England and Wales are shown in Table 4. Although the water balance contains a number of fairly crude assumptions, and requires further work, it does provide some interesting insights into the extent of exploitation of water resources in the various regions:

i) in the Thames region the gross amount of abstraction probably exceeds the total resource, but supplies are maintained by the re-use of sewage works discharges;

ii) the largest unexploited water resource is in Wales;

iii) south west also appears to have significant unexploited resources.

It should be noted that the results of the water balance analysis show the extent of the total water resource which is being used at present. It does not show the extent to which developments have taken place which will allow an increase in use in the future. Thus, for example, the water balance for the Northumbrian region shows that the resource for the region is little used at present, but it does not show how the resource has been developed by the construction of Kielder reservoir to allow increased use in the future.

To date, the water balances have been calculated for the individual NRA regions, and this has enabled the regions with under-exploited resources to be identified. Further similar work can now be done on a catchment by catchment basis within the region to identify those rivers with potential for further development. This will be done during the next phase of the study.

Is this necessary.

3.2 Constraints

3.2.1 Environmental Implications

The effects of over-abstraction of surface water are more immediately apparent than for groundwater abstraction, but the situation is in its own way just as complex.

Perhaps the most obvious requirement is protection of very low flows, and the need for an adequate residual flow. The concept of a Minimum Acceptable Flow (MAF) is enshrined in legislation but it is of limited relevance to natural streams. The idea of such a minimum maintained flow is only really meaningful in rivers with large, main-stream storage reservoirs (where the compensation flow represents a MAF), or where the flow regime is quite unnatural in some other way - eg by low flows being greatly modified by pumping (eg from mines - River Wear; or land drainage, such as some Anglian rivers). For most rivers a prescribed flow or "hands off" flow is a more valid concept.

Levels of prescribed flow appropriate to catchment type, water quality etc, are perceived environmental requirements. The 95% exceedence flow (Q95) is often used as a starting point, and would generally appear to be valid as a low flow that occurs naturally fairly frequently. While a simple rule which allowed abstraction to take place as long as a residual flow equal to or exceeding Q95 is often adequate for small abstractions, operation of a major source under such a regime would lead to extended periods with flow approximating to Q95. While this may be acceptable in some lowland, ponded rivers (subject to satisfactory water quality), it is definitely not so for more upland streams whose ecological character depends upon a variable flow regime. In such situations a 50% take rule, subject also to a Q95 prescribed flow, protects much of the streams character. However, a series of such abstractions would quickly whittle away the flow in exceedence of the Q95.

Where migratory fish are a consideration, protection of some low to medium flows, associated with fish movement, can be as important as protection of very low flows. In this situation rather complex operating rules are required to reduce impact to a minimum level. Some NRA regions have been developing methodology for setting prescribed flows appropriate to the river type and the use/interests to be protected. As with groundwater abstractions, the next two decades are likely to see development of operating rules that reduce the potential take of surface water at times of low and medium flows.

Taking water at or near the tidal limit does of course reduce the impact on most of the river, but a good flow of freshwater in to the estuary is needed to stimulate migration of migratory fish. Halcrow have been exploring the scope for "spate sparing" (cessation of surface water abstraction for a few days during a summer spate) to protect salmonid migration in the South West Region.

Imposition of significant periods of zero unsupported abstraction does of course require alternative sources for such times, or reservoir storage. Using groundwater sources only at such times may be a viable option (such as the Southern Water Candover scheme). However, the hydrographic nature of groundwater fed streams means that, unlike surface water streams, distribution of Q95 is very clumped. For example, flows on the Hampshire Avon fell below Q95 in only six years between 1975 and 1990. These were 1975 (16 days), 1976 (238 days), 1984 (38 days), 1987 (1 day), 1989 (80 days) and 1990 (95 days). Clearly provision of an alternative source for such times would be a costly problem, with its own potentially significant, if infrequent, environmental impact.

There may be considerable scope for diurnal modulation of abstraction (eg 12 hours off, 12 hours at double rate) at tidal limit abstractions to protect fish movement.

It is suggested, however, that further significant development of surface water abstraction is likely to involve increased reservoir storage, and/or increased reliability of existing reservoirs by pumped storage. In general terms, reservoirs represent a significant environmental bonus, despite the inevitable initial local objections.

3.2.2 Water Quality

There are two fundamental water quality considerations to be taken into account in relation to development of a surface water source:

- will the abstraction cause deterioration in downstream water quality, due to reduced dilution of pollutants?
- can the abstracted water be treated to potable quality?

A third issue - deterioration of water quality in long trunk mains - is occasionally a problem and is thus relevant to some strategic options. However, operational means exist to overcome this difficulty, and the associated cost is relatively minor in relation to overall transmission costs, so it is not considered further.

The need to maintain downstream water quality is now a recognised consideration in determining new abstraction licences and establishing prescribed flows. In-river and estuarine quality implications are assessed whilst preparing Environmental Statements, and in some cases potential scheme yields have to be reduced in order to ensure that acceptable standards are maintained.

The river quality surveys for England and Wales provide a useful guide to the treatability of surface water to potable standards. Through these, sections of each main river are designated 1-4 according to their potential use, as shown in Table 5. It may be seen that Classes 3 and 4 are unsuitable for potable use; obviously, if quality of Class 3 rivers can be improved, they then have potential for potable use, albeit with advanced treatment.

The most recent survey was undertaken in 1990, but results have not yet been published. A guide to rivers with poor or bad quality in 1985 is given in Table 6.

In 1985, some 9% of rivers (3,500km) were of poor quality and 2% (800km) of bad quality. Conversely, some 89% (34,700km) were of good or fair quality, and, by inference, suitable for potable use. However, these results should be treated with some caution, since the Lower Trent, for example, is shown as Class 2; it is understood that blending with water from other sources, as well as treatment, is necessary before Trent derived water can be used for potable supply.

Many of the localised problems in 1985 related to sewage works discharges and, with the planned expenditure on improving effluent discharge quality, many class 3 rivers should achieve class 2 in the medium term. Conversely, the implications for major rivers of increasing salinity loadings due to such factors as flue gas desulphurisation and denitrification plants at waterworks in the future are not known.

As with groundwater, the long term implications of exotic pollutants such as heavy metals and pesticide residues are not fully understood.

3.3 Opportunities

The existing water supplies in England and Wales have been developed almost entirely since the middle of the last century. When these supplies were first developed, the most important design consideration was the need to provide clean drinking water. In mid-Victorian times, the absence of water treatment technology meant that the two favoured types of development were direct supply reservoirs built in upland catchments, and groundwater supplies also generally from upland catchments. Gradually, as the best upland sources have been exploited and water supply technology has advanced, there has been a tendency for more abstraction of water from lowland rivers, frequently in conjunction with pumped storage reservoirs or river regulating reservoirs in the upper catchment. Throughout this period of development, the priorities have been the provision of safe drinking water at minimum cost. These factors have taken precedence over the need to consider water as a scarce resource and the avoidance of environmental damage. The consequences have been:

i) the construction of direct supply reservoirs in upper catchments has reduced the potential for river regulating reservoirs, which are more efficient in water resource terms;

ii) most existing groundwater developments are used to pump water directly into the supply. In water resource terms, it is more efficient to use groundwater either in conjunction with surface water abstractions or for river regulation, combined with lowland river abstraction schemes. These different types of groundwater development make better use of the storage in aquifers and are potentially less damaging to the upper reaches of rivers.

iii) the concentration of existing water supplies in the upper parts of catchments means that there is reduced scope for re-use of water returned to rivers via sewage treatment works. A notable exception to this is the Thames catchment, where the construction of large off-river storage reservoirs to the west of London has enabled substantial re-use of sewage effluent.

This history of water supply development has left three major opportunities for further water resource development. Firstly, the lower parts of most river catchments are under-developed, leaving scope for more lowland abstractions schemes combined with pumped storage. Secondly, the development of resources in the lower reaches of river will allow more re-use of sewage effluent. And thirdly, there is some (albeit limited) scope for change in use of groundwater resources for river regulation and conjunctive use with surface water resources (see Section 2.3.3).

The analysis of regional water balances described in Section 3.1 has shown that there is potential for transfer of water from the north and west of the country to the south and east, where the rainfall is lower and the population higher.

To date, in planning the strategy for sewage disposal, there has been little attention given to the use of sewage works effluent as a water resource. The planning of lowland water supply schemes should be undertaken with potential changes to the sewerage system in mind. The cost of transferring sewage effluent up river catchments can be offset against the reduced need for reservoir storage to support lowland abstractions schemes. This could be particularly important when the environmental impact of new reservoir construction is taken into account.

The existence of large impounding reservoirs on comparatively small upland catchments presents the opportunity of increasing resource reliable yield by pumped augmentation. Such potential is generally present where the existing reservoirs have a "re-fill period" of more than one year. Such schemes are already under investigation for the existing Chew, Wimbleball and Grafham reservoirs. There is likely to be scope for further schemes elsewhere. There may also be potential for change of use of existing direct supply reservoirs to river regulation, giving higher yields in conjunction with lowland abstractions.

4 PRELIMINARY REVIEW OF STRATEGIC OPTIONS

4.1 Demand Management

Demand management may be defined as the deliberate application of policies to influence the quantity and timing of demand for water. The aim is to achieve an appropriate balance between the level of expenditure and the level of service to the customer. It can be categorised into three main areas of interest:

Leakage (unaccounted for water)
Metering allied to tariff structures
Public awareness and levels of service

Leakage - more correctly termed unaccounted for water (UFW) - cannot be determined directly when the public supply is unmetered. It is the balancing item once metered and unmetered domestic and industrial demands are subtracted from the volume of total supply. It may contain water losses due to under recording by source and consumer meters, or illegal unmetered connections, as well as leakage from the service reservoirs; distribution mains, service pipe connections and from consumers' plumbing systems. The definition of leakage varies greatly between the water companies, and therefore the stated unaccounted for water percentage demand spans from 9% to 30% (Inception Report Table 8). These differences may be balanced by the value of per capita consumption, with high values equating with low unaccounted for water estimates and vice versa. For example, in Newcastle & Gateshead Water the average per capita consumption was assessed to be 155 l/hd/day, and unaccounted to represent 14.6% of total demand, while in Yorkshire Water plc the same components have values of 125 l/hd/day and 30.3% of total demand. The range of methods used to estimate per capita consumption is shown in Table 7.

This variance makes it difficult to appraise the leakage targets which the water companies have proposed to meet within the next ten years. A review of various texts indicates that to reduce UFW below levels of 16% - 17% is very difficult to achieve, and for old distribution systems in urban areas levels below 20% may require intensive leakage monitoring.

Although leakage control is a valid demand management tool, some of the water companies may be over estimating its value. There is an optimum level of waste detection past which the costs of surveillance exceeds the value of the water in terms of treatment and distribution. Reducing UFW further means that the marginal cost of saving the water will eventually exceed the cost of new water resources, making leak detection effort uneconomic. As the per capita consumption increases in the future, so will the need to increase mains water pressures to meet demand during peak periods, and greater pressures will have the effect of exacerbating the leakage problem.

The per capita consumption of water in differing countries is effected by climate, prosperity and relative cost of water. In the large cities of the United States, consumption figures of above 400 l/d have been recorded. In Italy, where water has a 'comfort' value, the average consumption in 1983 was 215 l/hd/dy, compared with 125 l/hd/dy in this country. The United Kingdom is one of the few western European countries not to meter domestic supply, but still it apparently has one of the lowest per capita consumption figures. In Southern region, the consumption in metered housing was recorded in 1988 at 174 l/hd/dy compared with estimated unmetered consumption of 147 l/hd/d; however, these figures should be treated with caution, since metering took place on new rather than existing properties.

The impact on the demand after introduction of metering varies greatly and the dramatic reductions recorded in Philadelphia USA (45%) and Boulder, Colorado (36%) are unlikely to be mirrored in Britain, due to comparatively low initial consumption figures. The WRC second interim report on the National Metering Trials (July 1990) showed consumption reduction of 12%, but it has yet to be seen whether this is a permanent shift in people's attitude to water or a short term reflection to metering charges.

In conjunction with full or partial metering, a structured tariffing policy may help in reducing peak demand. Excessive outdoor usage of water, which is a significant component of peak demand, may be deterred by a seasonal loading of water pricing. During the National Trials various tariff programmes are to be evaluated.

Engendering a public awareness of a resource scarcity during drought conditions has in recent years helped to reduce demand into line with available resources. This is shown in Figure 2, where water consumption in the Thames region fell to 75% of the average yearly demand during the 1976 drought. Whether this voluntary control could be extended to normal summer conditions, even with large advertising campaigns, seems unlikely. A more successful approach may be a range of physical controls including:

- installation of water saving appliances;
- more stringent hose pipe regulation;
- mains pressure reduction.

Low water use appliances and hose pipe use reduction would no doubt be encouraged by a move toward general or partial metering.

The legal instruments to control the installation of inadequate fittings and appliances are contained in the 1989 Water Byelaws. The byelaws require the consumer not to cause waste, misuse, undue consumption or contamination of an undertaking's supply. Although there is no mandatory requirement, most responsible manufacturers submit their products for testing to the Water Byelaws Advisory Service (WBAS), which produces a list of approved products. The WBAS advises not only manufacturers, but also building professionals and the general public in installing appliances, and undertakes research and development into water efficient systems. The scope to enhance this service will be reviewed.

4.2 Water Re-use

Increasing pressure on surface water supplies, especially in the lower river basins, has led to a high level of indirect water re-use being practiced in Britain. Treated sewage effluent is contained in approximately one third of the water abstracted for public supply. In London, analytical studies of the raw water withdrawn from the Thames for public water supply, have indicated an average treated sewage effluent proportion of approximately 13%. Thames Water Utilities are proposing further indirect water re-use schemes by transferring effluent from the London STWs upstream to either Windsor or to the river Lea, to support increased abstractions. It has been estimated that between 100-150 Ml/d, which would otherwise be discharged into the tidal estuary at Deephams STW, could be reused in this way.

In contrast, direct water re-use has not developed on a widespread basis, but rather as a response to specific local conditions. Sewage effluent is used directly in many countries worldwide for municipal agriculture, and industrial and even public water supply usage. In areas where heavy agricultural or industrial demand is experienced, re-use of secondary treated effluents can reduce the demand for water suitable for potable supply, and expenditure on water treatment.

In any direct re-use of effluent scheme for agriculture, health considerations are paramount. In this country they are covered by the DoE circular 97/77, which is concerned with the deposit of sewage on land. Use of effluents from industrialised areas is limited, due to the possible heavy metal content. Suitable effluents need to be disinfected to reduce bacterial pathogens, viruses, protozaa and helminths; this is especially necessary for crops which are normally eaten raw. Large scale expansion of irrigation by sewage effluent is restricted by the cost of transporting the effluent to the supplier, and the marketability of the crops.

The main industrial effluent re-use application is for cooling water in power generation, oil refineries, steelworks, and paper and chemicals manufacture. The constraints on the practice include reliability of supply; increased metallic corrosion with higher water conductivity; scaling problems with the precipitation of inorganic salts; increased biological growth and fouling. In 1977, only 50 Ml/d of the estimated 70 x 10^3 Ml/d water used in the United Kingdom for cooling was obtained from re-used effluents.

The re-use of effluent for potable water supplies could help to increase resources, but it is a contentious subject with public health authorities and the general public. To accomplish the high degree of treatment and reliability for potable re-use, advanced processes such as nutrient removal, recarbonation, filtration, activated carbon adsorption, and demineralisation by reverse osmosis are needed. The technology is proven and treatment plants exist in the United States, where waste water is cleaned and injected into potable water aquifers.

Health risks due to the mixture of residual inorganic and organic contaminants that remain, even in highly treated water, are not yet fully understood. Direct pipe to pipe re-use may not be yet acceptable; to assuage public opinion and reassure public health authorities, the treated water may have to be diluted by using it in aquifer recharge schemes or discharging it into drinking water reservoirs.

4.3 Inter-Regional Transfers

A review of the resource development plans of the water companies has identified three large inter-regional water transfer schemes, which may in the future be viable.

a) Severn-Thames Transfer
b) Trent-Witham Transfer Enlargement
c) Kielder-Yorkshire Ouse Transfer

These schemes are either already partially established, or have been the subject of intensive feasibility studies.

The envisaged Severn-Thames scheme was that the existing Craig Goch reservoir in the Elan Valley in mid Wales would be enlarged, and the increased storage used to augment dry weather flows in the Rivers Wye and Severn. The increased amount of water available for abstraction from these two rivers could then be transferred to the Thames.

In 1980, the Central Water Planning Unit concluded that up to 680 Ml/d of water would be available for transfer. They recommended abstraction of water on the Severn near Tewkesbury, transferring it by pipeline to either the Upper Thames or the tributary River Cherwell. The first transfer stage of 225 Ml/d was shown to be viable on engineering, economic and environmental grounds, but environmental objections were foreseen to later stages, especially in the Cherwell where enlargement of the river channel was required. The full cost of Stage I at 1990 Q(4) prices based upon the report findings is £255M, which compares with the estimated £300M (based upon £1.5M/Ml yield) required to construct the proposed upper Thames pumped storage reservoir.

The transfer scheme could, if fully developed, satisfy Thames Region's demand up to the year 2011, and with a new pumped storage reservoir, until 2021. If it were to proceed, it would require the collaboration of Thames Water Utilities Ltd, Severn-Trent Water plc and Dwr Cymru, as well as the NRA. A flexible management and charging system would be needed.

The completed first stage of the Trent-Witham link, transferring water from Severn-Trent to Anglian region, is designed to move up to 136 Ml/d to the River Witham. Water is subsequently transferred to the Toft Newton reservoir and used to regulate the river Ancholme flow by up to 118 Ml/d, of which 59 Ml/d is supplied to industry by Anglian Water, and up to 20.5 Ml/d is directly abstracted for industrial and agricultural use.

At present, the water from the Trent is not of sufficient quality for domestic use without blending, and future planned developments of regulated flows up to 236 Ml/d in the river Ancholme are for additional industrial and agricultural use. Although in recent years the gross conventional water quality deficiencies of the Trent are improving, the subtle presence of exotic pollutants continues to present problems in treating the water to potable standards. Also the chloride loading of the river is likely to increase significantly in the future, due to the combined effects of flue gas desulphurisation, mine dewatering and denitrification at treatment works. Anglian have estimated that there is a potential 500 Ml/d yield from the Trent which, if it can be utilised, would meet forecast demands post 2021.

In the Northumbrian region, regulation water released from the Kielder reservoir can be transferred from the river Tyne into the rivers Derwent, Wear and Tees by an interconnecting pipeline and tunnels. Regulation of the river Tees is largely determined by abstraction requirements for public water supply in the lower reaches. In the 1960's, WRB development plans proposed extension of this scheme, to mobilise water from Northumbria to Yorkshire by pipeline connection between the Rivers Tees and Swale. Yorkshire have undertaken studies into this option but have found that development of local groundwater resources is more economic for local needs at present.

4.4 Water Grids

In the late 1960's the then Water Resources Board (WRB) undertook a series of water resource studies in England and Wales. At that time, expected future population was based on forecasts made in 1965, which projected an increase of about 17.6 million on an existing population of 48.6 million, to give a total of 66 million by 2001.

In order to supply this population and meet rising per capita consumption demands, the WRB recommended a large scale programme of construction including direct supply and pumped storage reservoirs, tidal barrages for estuarine storage, river regulation schemes and interconnecting supply pipelines. The proposals were aimed at integration of resources nationally, to provide flexibility of deployment and to increase the combined resource yield.

The WRB plans could be thought of as the first 'National Water Grid' - a description analogous to the electricity grid operated by the National Grid Company. The difference in physical transmission requirements between water and electricity will not allow the management flexibility achieved with the electricity grid but, given enough capital and operational expenditure, large scale water distribution is possible.

In the intervening years, the old river boards have been amalgamated firstly into regional water authorities and recently into the NRA and the 35 water supply companies. With the water industry transferring from public to private control, the scope for resource planning and development has contracted from a national to a regional level. A resistance to large regional transfers may have evolved, with companies favouring independent local resource development.

Integration of regional resources in the form of 'mini' grids has already taken place, notably in Yorkshire and South Wales. In Yorkshire linking of the source reservoirs in the Pennines with the industrial areas has increased the region's operational flexibility. For example:

- peak demands can vary from area to area and by linking resources the total maximum peak can be reduced;
- supply can be guaranteed when local failures occur;
- areas can be sourced from a mixture of ground and surface water resources, ensuring that no single source is over exploited, water quality is achieved with minimum treatment, and abstraction facilities are operated close to the optimum efficiency.

Severn-Trent plc is proposing to lay a treated water main linking the Severn Valley sources to provide security against pollution incidents and failure. Extending this scheme to the Thames Valley could assist Thames to meet peak demand during drought years. How

4.5 Transfer by Sea

Transfer of water using bulk carrying or tanker vessels could be a conceivable contingency strategy during severe drought conditions. In 1984, Northumbrian Water undertook a rescue plan to tanker water to serve Gibraltar, when supplies there were cut off following the closure of the border with Spain. The Northumbrian NRA have suggested that the operation was more successful as a public relations exercise than as a commercial venture. Additional studies are to be carried out in order to establish the costs of such an exercise, and the extent of suitable supply and reception facilities around the country. The feasibility of any such operation will depend greatly upon the 'value' of water during a severe drought.

A cursory review of the draught requirements and handling implications of importing freshwater via icebergs shows such an option to be far more complex - and thus more costly - than using bulk carriers.

The construction of the Channel Tunnel and single European market in 1992 has heightened our awareness of the proximity of Europe and possible import of resources.

The French already export electricity to the UK's National Grid and, with French investment in the water industry, importation of water may be an option. From initial enquiries, however, installing a water main inside the channel tunnel is not viable, due to the restricted space. A rough estimate for laying a new main across the channel, based upon costs of a recent Jersey sewage outfall (£3.7M/km), gives a capital cost of £140 million. This is not an unreasonable figure, but any scheme is dependant on the availability of water in France.

Investigations have indicated there is at present a small water surplus in the Picardy region of France, but this will be required for the expected future growth due to the Channel Tunnel. Transportation of water into Picardy or development of resources in the area would nullify the scheme's advantages.

TABLE 1 - GROUNDWATER RESOURCES BY REGION						
NRA Region	Resource Estimate (NRA est)	Abstraction			Planned Schemes (upto) (Ml/d)	Resource Balance (Ml/d)
		Licensed Amount (Ml/d)	Actual Amount (Ml/d)	Actual 1985 (Ml/d)		
Anglian	1914.8	1410.4	*	986.0	215.0	289.4
Northumbrian	*	159.7	*	110.0	12.0	*
North West	2223.2	1150.6	*	471.0	*	1072.6
Severn Trent	1999.7	1558.1	*	1063.0	100.0	341.6
Southern	*	2944.1	*	996.0	87.0	*
South West	*	77.4	*	114.0	*	*
Thames	*	1904.8	*	1802.0	415.0	*
Welsh	4174.6	174.9	80.8	138.0	100.0	3899.7
Wessex	2808.0	1116.5	735.4	408.0	1.0	1690.5
Yorkshire	3425.3	680.8	*	348.0	220.0	2524.5
Totals	*	*	*	6436.0	*	*

Note: The balance is based on the estimated recharge and not the safe yield of the resource which is likely to be considerably less. The only exception is NRA Anglian Region where the yield has been determined as a maximum potential abstraction.

* Data are unavailable

TABLE 2 - GROUNDWATER RESOURCES BY AQUIFER FOR EACH NRA REGION

Southern - Data are available
South West - Data are unavailable
Thames - Data are unavailable

Region: Anglian						
Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction		Planned Schemes (up to) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)		
Crag	*	115.7	26.3	*	*	*
Chalk	)	1462.5	1103.7	*	*	*
	) 2611.0					
Greensand	)	92.1	59.3	*	*	*
Oolitic Limestone	*	2.4	9.1	*	*	*
Lincolnshire	235.6	189.3	154.7	*	*	*
Spilsby Sandstone	*	24.9	31.9	*	*	*

NRA Anglian determine the resource as a maximum potential abstraction

Region: Northumbrian							
Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction			Planned Schemes (upto) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)	Actual 1977 (Ml/d)		
Magnesian Limestone	219.2	*	136.8	*	*	*	*
Carboniferous Limestone	*	*	22.9	*	*	*	*

TABLE 2 (Contd)

Region: North West

Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction			Planned Schemes (up to) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)	Actual 1977 (Ml/d)		
Permo-Triassic Sandstones	906.8	920.0	873.3	*	*	*	*
Coal Measures	*	132.3	38.0	*	*	*	*
Millstone Grit	*	235.8	77.0	*	*	*	*
Carboniferous Limestone	*	818.0	35.3	*		*	*

Region: Severn Trent

Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction		Planned Schemes (upto) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)		
Permo-Triassic Sandstones	1446.6	1804.1	1487.9	1076.3	*	*
Carboniferous Limestone	*	67.8	59.2	29.9	*	*
Magnesian Limestone	109.6	127.7	11.1	18.2x	*	*

x - Includes discharge from Manton Colliery

TABLE 2 (Contd)

Region: Welsh

Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction		Planned Schemes (upto) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)		
Quaternary Deposits	*	582.2	55.9	27.7	*	*
Lower Lias	*	159.5	0.0	0.0	* *	* *
Permo-Triassic Sandstones	74.0	5.8	14.0	0.0	*	*
Keuper Marl	*	5.8	1.1	0.8	*	*
Coal Measures	*	1163.3	23.3	3.3	*	*
Millstone Grit	*	60.5	4.4	2.2	*	*
Carboniferous Limestone	*	1160.5	57.8	34.2	*	*
Old Red Sandstone	*	1037.0	18.4	12.6	*	*

Region: Wessex

Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction		Planned Schemes (upto) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)		
Chalk and Upper Greensand	2594.5	2808.0	1116.5	735.4	*	*
Permo-Triassic Sandstone	106.8	*	*	*	*	*

TABLE 2 (Contd)							
Region: Yorkshire							
Aquifer	Resource Estimate (IoH est) (Ml/d)	Resource Estimate (NRA est) (Ml/d)	Abstraction			Planned Schemes (upto) Ml/d)	Resource Balance (Ml/d)
			Licensed Amount (Ml/d)	Actual Amount (Ml/d)	Actual 1977 (Ml/d)		
Alluvium	*	14.2	15.3	*	*	*	*
Sands and Gravels	*	3.5	8.5	*	*	*	*
Chalk	882.2	694.8	141.8	*	*	*	*
Corallian	*	179.9	80.6	*	*	*	*
Oolitic Limestones	*	384.5	10.1	*	*	*	*
Permo-Triassic Sandstones	824.7	217.2	169.6	*	*	*	*
Magnesian Limestone	347.9	234.9	85.1	*	*	*	*
Coal Measures	*	586.0	48.4	*	*	*	*
Millstone Grit	*	675.7	67.0	*	*	*	*
Carboniferous Limestone	*	434.6	28.8	*	*	*	*

TABLE 3

Yields of Planned Groundwater Developments According to Scheme Type

To be modified

Region	Yields (Ml/d)			
	Direct Supply Schemes for Local Needs	Direct Supply Schemes from Mid/Lower Reaches of Major Rivers	Augmentation Schemes	Total
Anglian	60	≤50	85+	195+
Northumbrian	12	-	-	12
North West	30	-	-	30
Severn-Trent	≤90	30+	-	120+
Southern	28+	-	≤55	83+
South West	-	-	-	-
Thames	55	≤150	180	≤385
Welsh	≤80	-	≤10	≤90
Wessex	< 1	-	-	< 1
Yorkshire	20	-	200	220
TOTALS	376+	230+	530+	1136+

what if local is in mid/lower reaches?

Notes: + Indicates some data are not available

- Indicates no groundwater development planned

Table 4

EXISTING REGIONAL WATER BALANCES (PRELIMINARY)

net or gross from table 9

Region	Reliable rainfall (1) mm	Evaporation in drought year (2) mm	River MAF (3) mm	Total Ml/d Regional Resource	Inter-region transfer Ml/d	1989/90 Demand Ml/d	Resource Used (4)		Use Net of Returns (5)	
							Ml/d	% of Regional Resource	Ml/d	% of Regional Resource (6)
Anglian	549	534	1514	NEG	+175	2345	2520		1246	
Northumbrian	791	427	1661	7588	0	2257	2257	30	1364	18
North West	1095	503	13948	19481	+924	3275	4199	22	2884	15
Severn Trent	696	548	2345	6440	-204	4829	4625	72	3100	48
Southern	715	580	1124	2779	-130	1957	1827	66	976	35
South West	1075	610	2557	11309	-32	1241	1209	11	772	7
Thames	634	594	937	499	+129	4377	4506	903	1873	375(7)
Welsh	1201	580	6196	29979	-1064	4654	3590	12	1369	5
Wessex	782	580	1311	4178	+152	3088	3240	76	2324	56
Yorkshire	750	427	2206	9743	+50	2779	2829	29	1664	17

?

NB Figures sensitive to estimates of potential evaporation
Figures based on lumped regional data. Sum of sub-regional areas may differ significantly

where from surface + gw.

See notes on next page.

Too low

Notes

1. Reliable rainfall is 1 in 10 year annual rainfall (assume = 90% of mean annual rainfall).
2. Evaporation in drought year assumed approximate mean potential evapotranspiration plus 20%.
3. MAF assumed 12.5% of (Rainfall-evaporation) based on average year.
4. Resource used is 1989/90 demands + or - regional transfers.
5. Returns assume values in Table 9 of Halcrow Inception Report (IR) (May 1991) for private abstractions and 50% for PWS abstractions (T5,IR) except Severn-Trent (75%) and Thames (40%).
6. Use net of returns is resource less sewage works and private discharges upstream of tidal limit.
7. Methodology to reflect water balance not appropriate. Alternative methods to be investigate eg. flow gauging data.

TABLE 5

River and Canal Water Quality Classification Scheme

Decription	Class	Current Potential Use
Good Quality	1A	Water of high quality suitable for potable supply abstractions; game or other high class fisheries; high amenity value
	1B	Water of less high quality than Class 1A but usable for substantially the same purposes
Fair Quality	2	Waters suitable for potable supply after advanced treatment; supporting reasonably good coarse fisheries; moderate amenity value
Poor Quality	3	Waters which are polluted to an extent that fish are absent or only sporadically present; may be used for low grade industrial abstraction purposes; considerable potential for further use if cleaned up
Bad Quality	4	Waters which are grossly polluted and are likely to cause nuisance

TABLE 6

1985 - River Water Quality by Region

Region	River Length (km)	% of River Length in Class 3	Principal Rivers/ River Types in Class 3	% of River Length in Class 4	Principal Rivers/ River Types in Class 4
Anglia	4328	9	Sections of Cam & Nene; mttr	0.2	Middle Gipping
Northumbria	2784	2	Sections of Blyth, Tyne, Skerne and Tees; mttr	0.8	Upper Skerne, Lower Tees, mttr
North West	5323	17	Calder, Darwen, Mersey & tributaries, Weaver, Dane, Wheelock, mttr	5	Irwell, Douglas, Mersey, Weaver, mttr
Severn Trent	5150	12	Upper Trent, Erewash, Idle, Upper Avon, Upper Thame, Wreake, mttr	1	Upper Tame
Southern	1992	2	Middle Medway, mttr	0.2	Minor localised problems
South West	2941	6	Fal, Par, W Cornwall streams, mttr	0.6	Red, Axe tributory
Thames	3546	7	The Cut; Upper Mole, Wandle, mttr	0.1	Minor localised problems
Welsh	4600	6	Wych, Ystwyth, Lower Rhondda, Lower Ebbw, mttr	0.6	Minor localised porblems
Wessex	2467	6	Upper Stour; mttr	0.6	Minor localised problems
Yorkshire	5767	8	Wishe, Lower Ouse, Aire, Calder, Dearne Don, mttr	3	Upper Wishe, Middle Aire, Middle Calder, upper Don, Rother
England & Wales	38,896	9		2	

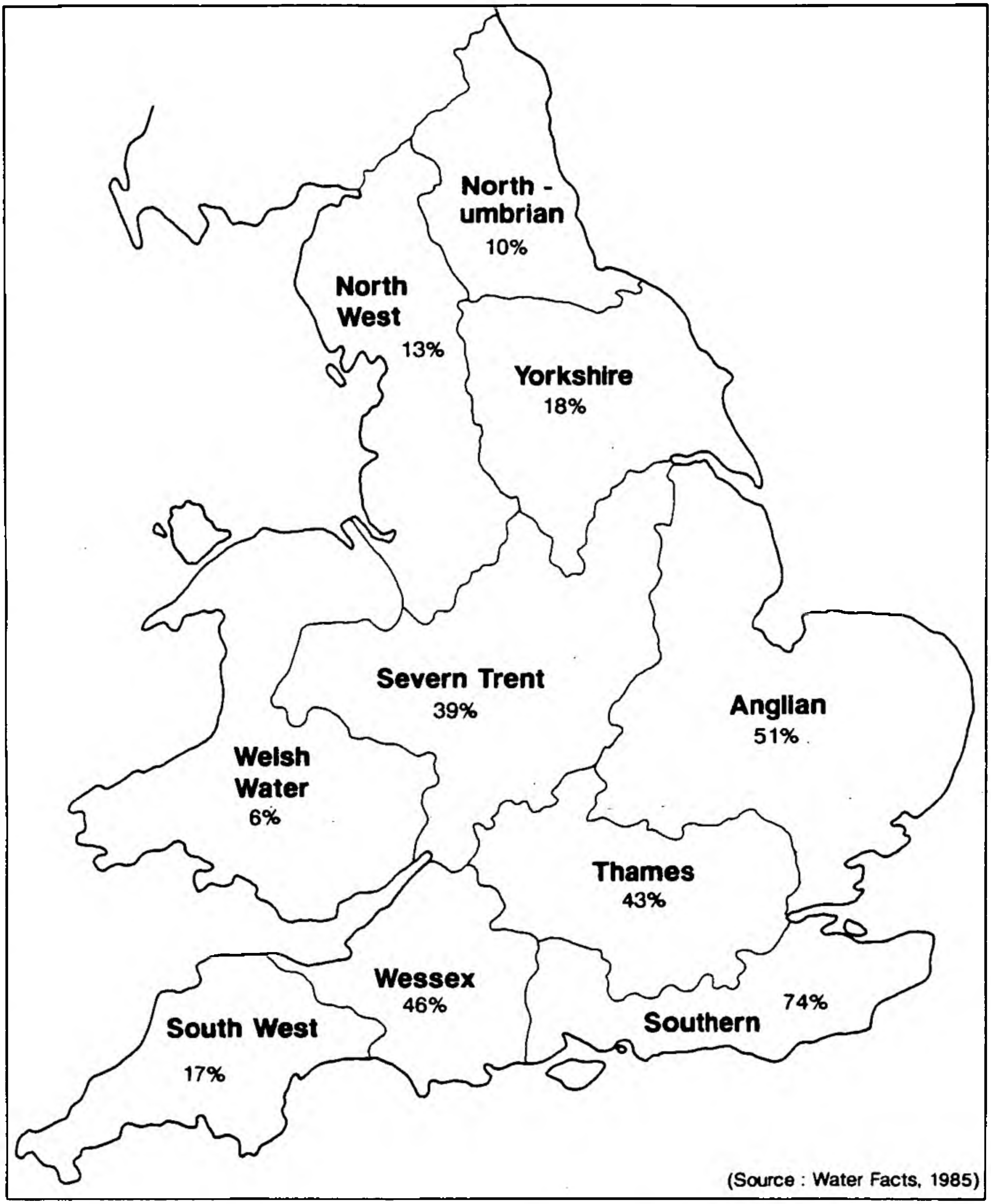
mttr = minor tributories throughout region

Source: River Quality in England and Wales 1985 (DOE Welsh Office)

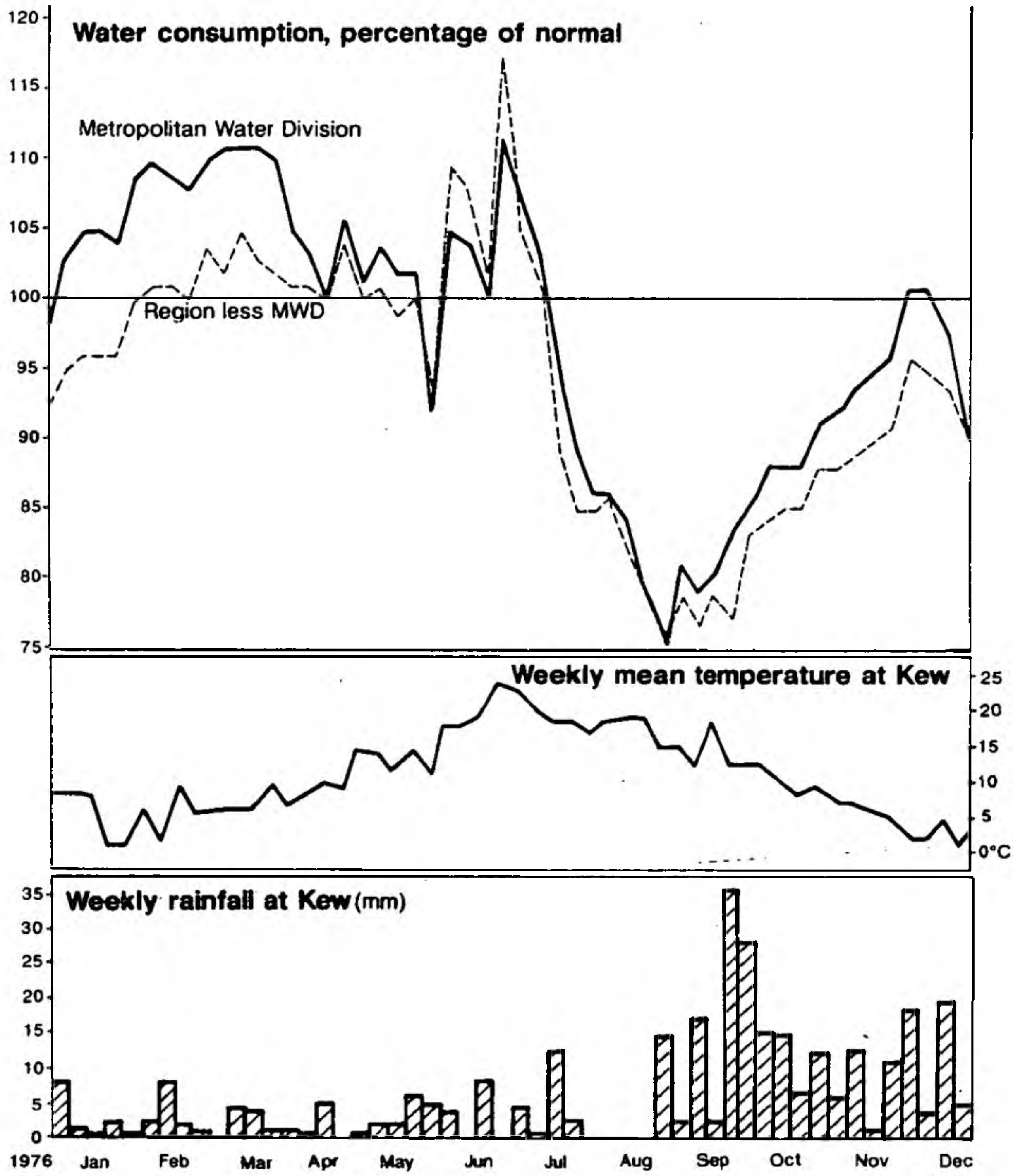
TABLE 7

Basis of Estimates of Domestic Percapita Consumption

Anglian (1986: 119-139 l/p/d) (1991: 136-150 l/p/d)	Anglian Water calculate unmeasured consumption, subtraction allowance for unmetered commercial and divide by the population to estimate percapita consumption. Figures for various types of use are estimated from this, and "subjective" predictions made on the basis of these figures
Northumbria	North East Water make predictions based on number of households. No data for the other two companies
North West (1991: 148 l/p/d)	Predictions are based on Binnies AMP report (1986). This report is commerical and confidential to the water companies
Severn Trent	Severn Trent Water run a domestic consumption monitor, whose results are available to other companies. No details provided
Southern (1988: 147.3 l/p/d) (1991: 157.9 l/p/d)	Water use in properties in 70 control areas is analysed. ACORN population profile data is used to apply this to each water company. A 1% growth rate based on historical data, is assumed. A 5% reduction for metering is assumed (this is an underestimate)
South West (1991: 140.7 l/p/d)	Surveys of 800-1000 representative households have been carried out peridically. Usage is broken down into components to make predictions
Thames (1990: 143 l/p/d)	Thames Water use preliminary studies of different social groups combined with ACORN data. Some of the other companies use detailed surveys
Welsh (Dŵr Cymru 1989: 141.5 l/p/d)	Percapita demand figures are produced, but no data provided on their estimation
Wessex	Figures based on report by Wessex Water Authority (1986). A representative sample of houses are metered to assess percapita demand, and component analysis is used to make predictions
Yorkshire (1988/9: 124 l/p/d)	Yorkshire Water use information from Severn Trent's Domestic Consumption Monitor, adapted by means of ACORN profiles. Predictions assume increasing ownership of water-using appliances and decreasing household size



PERCENTAGE RELIANCE ON GROUNDWATER
FOR PUBLIC WATER SUPPLY



Notes:

1. Water consumption included.

WATER SUPPLY CONSUMPTION 1976 IN THE THAMES REGION
(As percentage of normal)

After E.C.Reed, DFC, CEng, Director of Operations Thames Water, 1977.