HOWARD HUMPHREYS & PARTNERS LIMITED

CONSULTING ENGINEERS

HD

NATIONAL RIVERS AUTHORITY

THAMES REGION

WATER RESOURCES DEVELOPMENT OPTIONS

DRAFT FINAL REPORT

VOLUME 1 MAIN REPORT

February 1992

Record of Issue

Issue	Details	Originator	Date	Approved	Date
A	Draft for Client approval	[signature]	19.2.92	[signature]	20.2.92

Howard Humphreys & Partners Ltd
Thorncroft Manor
Dorking Road
Leatherhead
Surrey
KT22 8JB

Cobham Resource Consultants
Avalon House
Marcham Road
Abingdon
Oxford
OX14 1UG

WATER RESOURCES DEVELOPMENT OPTIONS STUDY
NATIONAL RIVERS AUTHORITY THAMES REGION
FINAL REPORT

CONTENTS

Volume 1 of 2

CONTENTS (Contd)

CONTENTS (Contd)

Page No.

CONTENTS (Contd)

Page No.

LIST OF TABLES

LIST OF FIGURES

Volume 2 of 2	**TECHNICAL APPENDICES**
APPENDIX 2	ENGINEERING AND HYDROLOGY DATA
APPENDIX 3	ENGINEERING COSTS
APPENDIX 4	WATER QUALITY DATA
APPENDIX 5	ENVIRONMENTAL APPRAISAL OF OPTIONS
APPENDIX 6	OUTLINE OF WATER RESOURCES MODELLING

NATIONAL RIVERS AUTHORITY - THAMES REGION

RESOURCE DEVELOPMENT OPTIONS STUDY

EXECUTIVE SUMMARY

Objective and Basic Assumptions

1. This study and report respond to the Commission and Terms of Reference for the project from NRA Thames Region. The overall objective has been to identify and assess feasible water resource development options to meet estimated growing demands for water in Thames region to the 2021 planning horizon (Section 1.1).

2. Future demand forecasts have been provided by the NRA for the purposes of this study. Demands are expected to exceed present water resources capacity by a substantial margin, whilst environmental and water quality requirements also increase.

3. The study has been subject to certain basic assumptions viz.

- adoption of given demand forecasts;
- environmental and water quality requirements met by imposed constraints rather than by resource development per se;
- continuance of present arrangements relating to residual flows at Teddington (Section 1.4).

4. Surface water abstraction will be subject to prescribed residual or minimum acceptable flows. As a consequent further continuous run-of-river abstraction through drought periods will not be an acceptable option, necessitating storage

for reliable supplies. Only limited further groundwater abstraction will be feasible on environmental grounds, in locations where the impact on water levels and base flows is not critical (Section 1.5).

Present Resource/Demand Balance

5. Average annual public water supply demand for Thames region as a whole in 1991 was 4031 Ml/d, compared with a reliable yield of existing public supply sources of 4224 Ml/d indicating a small current regional surplus of less than 5% (Table 3.2).

6. More critically, the 1991 demand in the London supply area was 2125 Ml/d met from a resource system reliably yielding 1970 Ml/d ie. a theoretical present deficit of 155 Ml/d for London (Table 3.2). For TWUL supply areas as a whole, present average demands and resource output are virtually in balance but with no margins for growth or demand and operating variations. The other water companies in the region are currently in surplus under normal conditions.

Non-Public Supply Demands

7. There are large differences between quantities authorised by licence to be abstracted, and quantities actually abstracted. These abstractions vary greatly in their impact on resources according to whether they are consumptive uses or whether largely returned to source and thus a borrowed use. The total gross quantity licences for direct non-public supply uses is about 12900 Ml/d, of which less than 500 Ml/d is believed to be largely consumptive uses. Of this only some 200 Ml/d was actually abstracted in 1990. This is about 5% of the regional public supply demand. Growth of direct demand has been slight in recent years and there is no reason to assume future needs meriting special resource development on a regional scale, especially in view of the existing licensed quantities not taken up.

Future Demands for Public Supplies

8. Forecasts of annual average demands for each of the main public water supply districts in Thames region for 2001, 2011, and 2021 as well as for 1991 are set out in Table 2.1. Peak weekly and summer seasonal demands derived by application of peaking factors are set out in Table 2.2 and 2.3 respectively. Alternative lower demands for 2011 and 2021 assuming achievement of targets for lower leakage losses are also given in Table 2.1. The figures imply a 26% growth of public supply demand overall in the 30 years 1991-2021 without additional leakage reduction, and 15% growth assuming leakage control targets are attained.

Commentary on Demand Forecasts

9. A brief review of the demand data and its basis has been undertaken in the study. Notably this shows an assumed 44 l/h/d average increase in domestic per capita consumption in the period 1989-2011, a 30% growth in 22 years, in contrast to almost unchanged per capita use in recent years. There appears to be a case for further critical assessment of demand forecasts (Section 2.2).

Demand Management

10. Demand Management as a means of influencing levels and incidence of future demands and hence the size and timing of further resources is not regarded as an important factor on the demand side of the resource/demand balance (Section 4.1).

Resource Reassessment

11. Apart from demand growth there are other reasons why further resources may be necessary. These include:

- climate change leading to greater variations of weather and increased uncertainty of resources.

- higher public expectations of reliability of supply.

- greater environmental and water quality constraints.

These may all cause a reduction in the reliable yield or resource value of existing sources, thus affecting the resource/demand balance (Section 8.1).

Future Deficits requiring Resource Enhancement

12. From the public supply demand forecasts and ascribed reliable yields of ongoing resources, future deficits have been derived to quantify additional resources required to satisfy future demands. These are set out in Table 3.2 and 3.3 for average annual and summer seasonal demands respectively. Table 3.4 gives the modified deficits with reduced leakage levels achieved.

13. The deficits suggest that initial planning of resource options for further public supplies yielding up to 1000 Ml/d is of the right order, while limiting subsequent stages of planning and promotion for the time being to about 500 Ml/d (Section 3.4).

Development Options Considered

14. Options initially considered were:

- Reservoir storage, including enlargement of existing reservoirs;
- Groundwater, including Artificial Recharge and Conjunctive Use in the London Basin;
- Use of Gravel workings for storage;
- Re-use of effluents discharged to the Tideway;
- Storage in the Thames estuary;

- Transfer into Thames from Severn, Anglian and further afield;
- Desalination of sea water.

Storage in the estuary transfers from more remote regions, such as from Wales, Northumbria and Scotland, and Desalination were rejected on grounds of cost, technical feasibility and environmental impact and were not taken to the next stage of assessment (Chapter 4).

Short-Listed Options

15. The remaining options were considered in greater detail as potentially feasible. Options within Thames region are:

- Thames-side Groundwater;
- London Basin Groundwater;
- Reservoir at Abingdon/Drayton;
- Enlargement of Staines Reservoir;
- Effluent re-use from Mogden and Deephams STW's diverted from the Tideway back to the freshwater resource system;
- Further surface storage in gravel workings and at Waddesdon associated with transfer options;

These have been assessed in terms of engineering implications, resource value or yield, water quality implications, environmental aspects and cost as detailed in Chapter 5.

Transfer options into Thames region are:

- From the lower Severn just above the tidal limit at Haw Bridge to the upper Thames at or near Buscot and/or to discharge to the proposed new reservoir at Abingdon/Drayton as and when built; transfers would be subject to prescribed residual flow limitations in the Severn and would not be supported by further dedicated storage for the Severn catchment.

- From Anglian region, as extensions from the Rutland Water-Grafham Water-Pitsford Reservoir system to discharge to one or more of the Thame, Stort and Roding as river-to-river transfers; also increase of existing treated water piped transfer from Grafham Water to Three Valleys WC and replacement of present bulk supply from TWUL to Essex WC with supplies from Anglian region. The Anglian transfers have been regarded as additions to further demands from within Anglian region and would be ultimately dependent on abstractions from the lower Trent and possibly a share of output from a new reservoir at Great Bradley.

These transfer options have been assessed like the Thames regional options as detailed in Chapter 6.

Resource Development Programmes or Scenarios

16. As no single scheme option would be sufficient alone to meet the whole forecast deficit, programmes of sequential resource development have been devised. Three such programmes or scenarios have been considered, with each of the foregoing scheme options featuring in at least one scenario. The two groundwater proposals feature as common initial elements in all three, with the scenarios differing thereafter.

Scenario 1 Thames regional solution, comprising in addition to the groundwater schemes, Drayton Reservoir, Staines Reservoirs enlargement, and Mogden effluent diversion and re-use.

Scenario 2 Thames regional solution plus Severn transfers. This comprises the groundwater schemes, Abingdon/Drayton reservoir and Severn transfers of up to 400 Ml/d maximum rate of transfer. The Staines redevelopment and effluent re-use do not feature in this scenario.

Scenario 3 Severn and Anglian transfers following the initial Thames groundwater schemes. This scheme in effect replaces Abingdon/Drayton reservoir with transfers from Anglian region of up to 300 Ml/d transfer rate to the Thame and Stort and from Grafham, to Three Valleys WC.17.

The costs and leading particulars of the three scenarios including sub-options are set out in Table 8.3. The significant additional cost of Scenario 3 without attendant benefits and advantages points to the final weighing of options between Scenario 1, the lowest cost Thames regional solution with its reliance on effluent re-use and heavy abstraction of unaugmented river flows in the middle reaches, and Scenario 2, with one major regional transfer from the Severn to augment the region's heavily used resources. Scenario 2 would involve additional water quality problems associated with the transfer to be overcome and would likely cost some 10% more than Scenario 1 (Chapter 7).

Recommendations

18. It is accordingly recommended that the Abingdon/Drayton reservoir, Severn-Thames transfer and Down Ampney gravel pit storage options which are key elements of the two preferred Scenarios should be examined in greater depth in further studies with a view to a combination forming the eventual preferred development programme.

19. To that end the report concludes with a number of more specific recommendations for further work and studies, including in relation to:

- Demand forecasting and management;
- Further refinement of the conjunctive use mode of operation of London Basin groundwater by modelling;
- Determination of conditions and constraints relating to abstraction for filling of and releases from Abingdon/Drayton reservoir;
- Various engineering, river management and fisheries aspects relating to Severn transfers;
- Further examination of opportunities for utilising gravel working storage particularly at Down Ampney;
- Further examination of acceptability of effluent re-use as a resource especially in relation to public perception and effect on migratory fish.
- Examination of likely losses in river augmentation options.

1.0 INTRODUCTION

1.1 Background

Howard Humphreys and Partners Ltd have been commissioned by the National Rivers Authority, Thames Region to undertake a broad scale desk feasibility assessment of potential water resource development option to meet forecast increasing public water supply demands together with further direct industrial and agricultural demands in the region to a planning horizon of 2021. The project follows a recent national overview study and concentrates on the needs and options for the Thames Region, taking assessments of options to a further stage of examination and refinement.

The Terms of Reference for the study as commissioned by Thames NRA are set out in Appendix 1.

Howard Humphreys and Partners have been assisted on the environmental aspects of the appraisal by Cobham Resource Consultants, Abingdon.

1.2 Summary of Present Position

The Thames Region is the most heavily populated and intensively developed catchment management region of Britain. It covers an area of 13,000 sq km and has a present population of 11.4 million of whom some 5.4 million live in Greater London. Water resources are much the most intensively used of any major catchment in Britain, and compare with the heaviest intensities worldwide. The River Thames as a consequence is highly developed, with flow, level and water quality affected by numerous large abstractions, effluent discharges and navigation structures regulated by the NRA.

Forecast future demands are expected to exceed present water resources capacity by a substantial margin, and at the same time environmental and water quality requirements are becoming increasingly demanding.

It is against this background that Thames NRA have sought an objective comparative assessment of potential water resources development options to further the planning process.

1.3 The National Study

The final report of the national water resources overview study - "Water Resources Planning - Strategic Options" has been submitted to the NRA and is currently under review. Strategic options for Thames Region include:

- artificial recharge in London
- major reservoir in Upper Thames
- Gatehampton groundwater
- redevelopment of existing reservoirs
- local groundwater schemes
- review of licence conditions
- effluent re-use from Deephams sewage treatment works
- national grid
- Severn-Thames transfer
- transfer from Great Bradley reservoir in Anglian Region

Potential yields from resource developments within the Thames catchment were estimated at 898 Ml/d, with around 1,500 Ml/d available from national inter-regional transfers to meet a forecast total deficit for public supply in 2021 of 1149 Ml/d. This allows for a reduction of 198 Ml/d in the present yield of certain existing sources in order to alleviate the effect of abstraction on critical low flows.

1.4 Basic Assumptions for the Study

From discussions with Thames NRA, Howard Humphreys have been directed to undertake the study on the following basis:

- Acceptance of demand forecast data provided by Thames NRA for the present purposes of this study, with no re-working of underlying data, but comments on the basis, consistency and general credence of the demand forecast data provided for the study.

- No general provision of water resources to overcome environmental problems, other than a reduction of 77 Ml/d in present source yield and corresponding increase in deficits in order to alleviate specific low flow problems. Also a general awareness of and provision for the effect of environmental constraints on future resource development and yields - see para 1.5 below.

- No water resources development provision to meet water quality improvements as primary objective. River water quality to be maintained at present levels by conditions and constraints on abstraction and effluent discharge. Water quality for supply to aim to at least maintain present standards by source selection and mode of operation.

- Assumed continuance of present Thames Water Utilities operating arrangements for the lower Thames reservoirs in respect of residual flows at Teddington weir.

1.5 Constraints on Water Resource Development

1.5.1 Surface Water Development

The NRA-Thames Region have indicated that any further surface water source development will be subject to prescribed residual flows (PRFs) or Minimum Acceptable Flows (MAFs) in order to protect downstream abstractions and to meet the needs of the aquatic environment at time of low flows. As a consequence any further resource developments to provide reliable supplies through a drought period will necessitate storage as opposed to run-of-river intakes. The lack of suitable on-river sites for gravity filled storage means that any such storage must be off the main feeder river and filled by pumping.

1.5.2 Groundwater Development

As a result of discussions with Thames NRA staff, Howard Humphreys have proceeded on the basis that only limited specific further groundwater abstraction is feasible on environmental grounds from the Chalk aquifer, and similarly virtually no further resources would be available from the Oolite formation in the upstream or western part of the catchment. Indeed as stated in 1.4 above, certain existing groundwater abstraction, in the Ver, Pang and Misbourne catchments must be assumed to be curtailed by a total of 37 Ml/d to allow for the restoration of flows that have been critically reduced by abstraction. In addition, a yield of 40 Ml/d from groundwater abstraction in the Darent catchment in North-West Kent, now outside the Thames region, will no longer be available.

1.6 Arrangement of Report

This report continues in Chapter 2 with the collation of present and forecast future demands, both for public supply and by direct abstraction. Chapter 3 applies these demand figures in conjunction with present resource yield estimates to arrive at quantified deficits at 10 year intervals to 2021, subject to stated assumptions to arrive at levels of resource development necessary by those dates.

Chapter 4 gives a broad review of the wide list of potential resource developments options considered in the study. Only those considered promising overall have been taken to the next stage of more detailed consideration and assessment as set out in Chapter 5 and 6. As no single development is likely to provide the solution for making good the future shortfall in resources capacity, and in order to provide meaningful comparisons of various options, three scenarios with differing combinations of potential schemes have been derived in the study and these are described in Chapter 7. In particular these have been the subject of resource-demand model runs by Thames NRA based on 70 years of hydrological conditions in the Thames catchment as a whole and using the forecast future public supply demand data at 2001, 2011 and 2021.

Finally Chapter 8 sets out provisional conclusions based on this modelling and the other assessments made in the course of the project, together with recommendations as to further work and studies needed to confirm the conclusions.

2. PRESENT AND FORECAST WATER DEMANDS

2.1 General

The water demands within the public sector used in this study, both present and forecast, have been supplied by Thames NRA. There has been no attempt to verify the build-up of the figures which were based on confidential information supplied to NRA by the water companies.

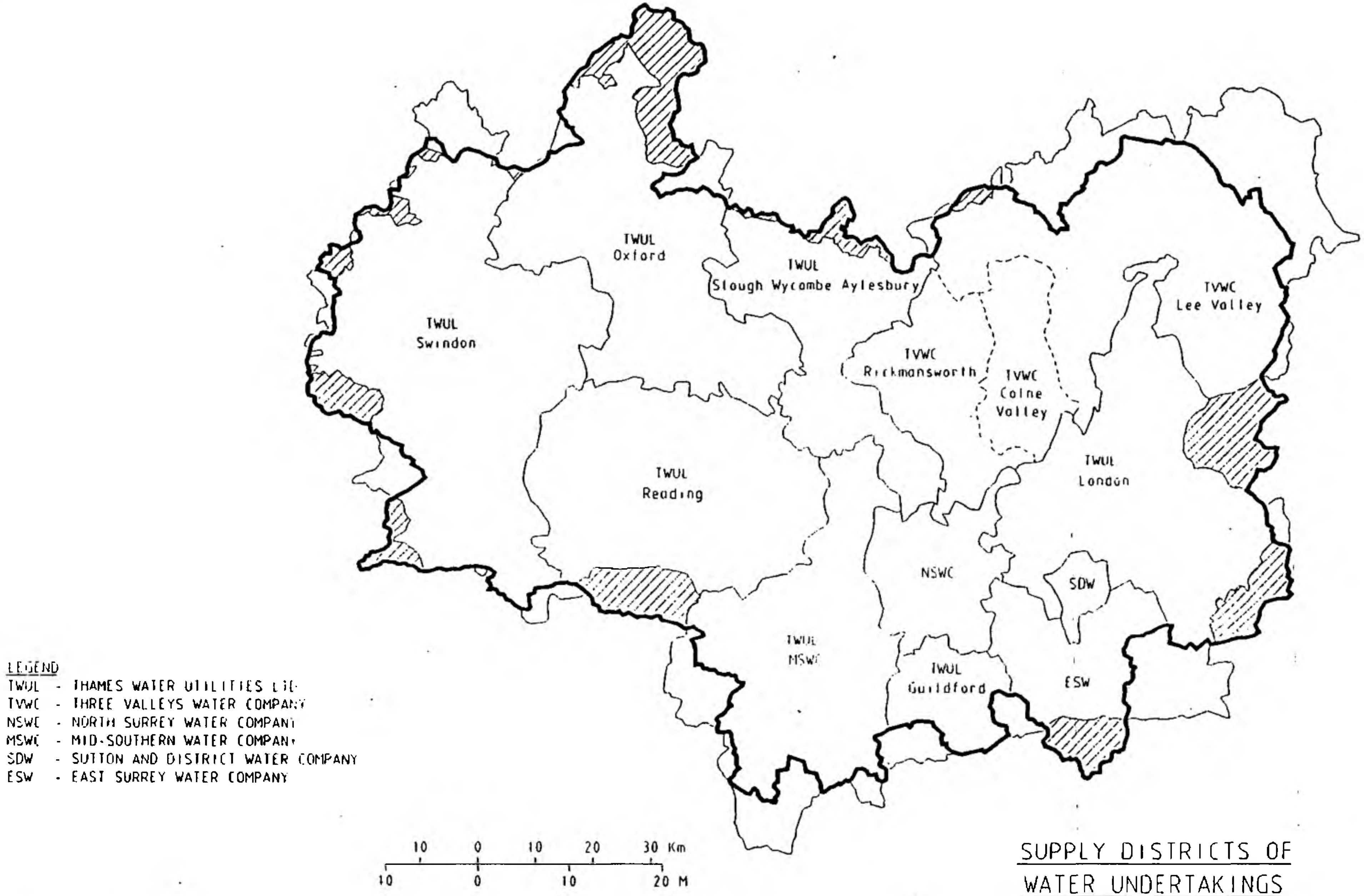
Water demands within the private sector have been derived from a current list of licence abstractions supplied by NRA.

Public water supply demand forecasts were provided by supply areas (Figure 2.1) covering groupings of demand zones within TWUL and other water companies. Some of the supply areas extend beyond the NRA boundary but logically are considered as contributing to the demand within the NRA area.

There are a number of areas on the periphery of the NRA boundary which fall within the supply area of water undertakers outside the Thames catchments. These areas have been excluded from the demand/supply scenario.

For their own planning purposes NRA have subdivided their area into 'strategy' areas. These areas, shown in Figure 2.2 are generally the same as the supply areas in Figure 2.1 apart from the west of the NRA area where the supply areas of Oxford, Swindon and Reading are rearranged to form the Upper Thames, and Kennet Valley & Reading strategy areas. For the purpose of this study, the Watlington strategy area has been included within the Upper Thames strategy area which contains the rest of the Oxford supply area.

The population within the Thames NRA strategy areas is estimated to grow from a present total of 11.4 million to 12.1 million by 2021.



SUPPLY DISTRICTS OF WATER UNDERTAKINGS

Figure 2.1

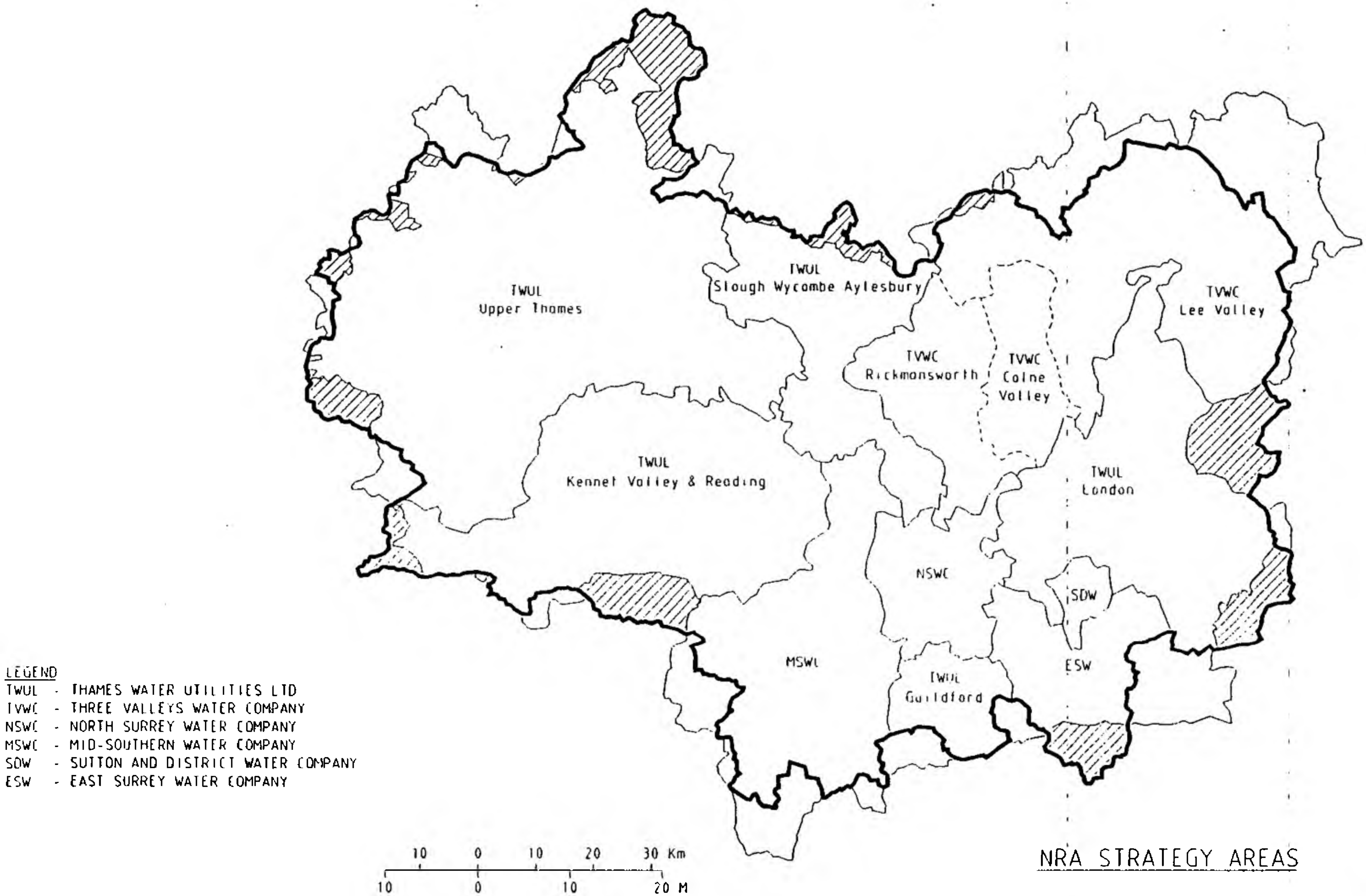

TWUL
Upper Thames
TWUL
Slough Wycombe Aylesbury
TVWC
Rickmansworth
TVWC
Colne
Valley
TVWC
Lee Valley
TWUL
Kennet Valley & Reading
TWUL
London
NSWC
SDW
MSWC
TWUL
Guildford
ESW
LEGEND
TWUL - THAMES WATER UTILITIES LTD
TVWC - THREE VALLEYS WATER COMPANY
NSWC - NORTH SURREY WATER COMPANY
MSWC - MID-SOUTHERN WATER COMPANY
SDW - SUTTON AND DISTRICT WATER COMPANY
ESW - EAST SURREY WATER COMPANY
10 0 10 20 30 Km
10 0 10 20 M
NRA STRATEGY AREAS

Figure 2.2

2.2 Public Water Supply Demands

2.2.1 General

Forecasts of average demands within the public water sector have been built up for the strategy areas by NRA from data provided by the water companies. The companies supplied their forecasts of average and peak daily demand up to 2011 incorporating their estimate of changes in the following categories:-

- domestic (virtually all unmetered at present)
- metered (industrial and commercial and limited domestic)
- unmetered commercial
- unaccounted-for

These estimates have been projected by NRA to forecast the 2021 demand in each supply area.

Whilst adopting these forecasts as the basis for this development options study, we have undertaken a brief review of the demand data provided and the assumptions behind them.

It is apparent from the water company demand data that by far the most significant component is the assumed future growth of domestic demand. This is assumed to increase by 38% in the 21 years 1990-2011. The per capita growth in that period is assumed to be 30%, the balance of 8% being attributable to population increase. By comparison, metered consumption (at present mainly industrial and some commercial) is forecast to increase by only 2%; commercial demand currently unmetered is forecast to grow by 36% (but with demand levels for this component less than one third of domestic) and 'unaccounted for ' water is assumed to reduce by 5% over the period.

The assumed 38% growth in domestic demand has to be seen in the context of virtually unchanged total and per capita domestic demand in the five years or so prior to 1990. Much therefore hinges on this assumption that there will be a sharp up-turn in domestic demand in the next 20 years.

Comparison and forecasts of separate component use in 2011 compared with 1989 for average and peak conditions shows that the greatest forecast growth in average demands (in l/h/d) are:

Personal washing:	44 to 62	18 increase
Clothes washing:	21 to 31	10 increase
Dish washing:	16 to 22	6 increase
Garden watering:	4 to 8	4 increase
Other components:	nett increase	6 increase

Total forecast increase in domestic use 44 l/h/d

These forecast appear to be very speculative without much firm evidence or research to back them up. For example, it would be remarkable if there were indeed a 40% increase as forecast in personal washing use. The past growth in this component accompanies the almost universal introduction of indoor plumbing and hot water. Now with increased use of showers as an alternative to baths, the widely accepted view is that this component is likely to remain practically static for the foreseeable future. Similarly there is little firm evidence for such large forecast growth in clothes and dish washing use. Modern appliances are being designed to use less rather than more water, and mechanical dish washers replace more frequent washing up by hand. On the other hand a forecast reduction in consumption for toilet flushing seems questionable and presumably stems from anticipated wider use in future of dual flush systems. The current view is that these, even if widely installed, may do little to reduce demand.

Undoubtedly the greatest potential for growth in domestic related uses lies in garden watering. This however is a use concentrated into certain peak periods and in particular neighbourhoods, rather than a general demand. Also it may be regarded as an optional demand that can be influenced by tariff structures.

Apart from domestic uses, the grounds for assuming such a large growth in unmetered commercial demand are not clear and also ought to be questioned.

There is no explicit provision in the demand forecasts for the possible impact of demand management generally or domestic metering in particular. However, there are alternative forecasts to allow for meeting targets for reduced leakage from mains. It is suggested that there should be similar alternative future demand forecasts to allow for the effect of the introduction of partial domestic metering in Thames region by 2011. This could provide the basis for a lower bound to the range of future demand growth assumptions.

The forecasts of demand growth and the per capita estimates for the various supply companies for 1990 and 2011 have been compared. It is suggested that in their formulation there are pressures to over-estimate future demand growth. Whilst it is desirable to be aware of this and to consider options for meeting the upper range of future demand growth, it is just as important to be aware of the uncertainties in such estimates, so that the eventual choice and phasing of options and commitment of development expenditure can be adjusted to a lower growth of demand should this turn out to be nearer the reality.

2.2.2 Average Daily Demands

The forecast average daily demands make allowance for a decrease in the quantity of unaccounted-for water over the planning period including anticipated reduction in leakage in the London area resulting from the construction of the London Ring Main. Over the region these leakage/distribution losses are assumed to decrease from about 26% of the total water put into supply at present to 20% in 2021. The companies have in addition proposed more ambitious leakage level targets falling within the range of 20% to 12% by 2011 which would have significant impact on demand levels.

The forecasts were presented to us by supply areas and, even though some portions of supply areas fall outside NRA Thames area, they have been allocated in total to strategy areas. In order to estimate the demand within the two strategy areas of Upper Thames and Kennet & Reading the sum of the forecasts for the Oxford, Swindon and Reading supply areas has been apportioned 55:45 respectively. The forecasts of average demand are given in Table 2.1 which also includes for the years 2011 and 2021 estimates of demand assuming the reduction in unaccounted-for water target figures of 5% are fully achieved.

2.2.3 Peak Daily Demands

The demand for water varies with time depending on a number of factors which are related to population behaviour and prevailing climatic conditions This variation in demand results in peaks and troughs about the average. In water resource planning the size of the peaks are of interest in order to determine the deficit, or surplus, between resource and demand.

The 'average' demand figures given in Section 2.2.2 are the average daily demands based on the annual forecast.

The data on demands supplied by Thames NRA did not include any forecast of likely peak requirements. However, estimated peak daily demands for 1990 and 2011 were given for each water undertaking, except TWUL, in the NRA report of March 1990 under Section 143(2)(a) of the Water Act of 1989.

Peaking factors have been derived from these estimated peak daily demands and extrapolated to 2021. The NRA Section 143(2)(a) report does not define the time period to which the peak demands apply but it is assumed that they relate to the peak week.

The peak factor is related to the size of the supply area with smaller peak factors for large conurbations such as London. Peak factors for the TWUL areas have been determined from a curve relating peak and average demands for other water undertakings in the Thames NRA region. The peaking factor for the large London area of TWUL has been estimated by reference to the peak factors given for several large UK undertakings.

The week peak factors and the corresponding peak week demands are given in Table 2.2.

It is felt that for long term strategic planning, source deficits based on weekly peak would lead to unnecessary overprovision, whereas planning for the annual average demand is not sufficient. The average demand over three consecutive months in the summer (the seasonal peak) is considered to be an appropriate and reasonable demand to be met by strategic sources as this relates to the critical period for summer depletion of surface storage. However, groundwater sources are required to have the abstraction and pumping capacity to cope at least with the peak week demand, assuming that service reservoir storage will balance most diurnal fluctuations.

A seasonal peak demand of 1.06 times annual average has been taken for all areas other than London where it is considered that a factor of 1.03 better reflects the variation of a large population over a three month period.

The seasonal peak factors and resulting peak demands are given in Table 2.3 which shows that the total 'seasonal' demand in the region is expected to grow from about 4200 Ml/d in 1991 to 5300 ml/d in 2021.

TABLE 2.1 PUBLIC WATER SUPPLY DEMANDS - ANNUAL AVERAGE (Ml/d)

STRATEGY AREA	1991	2001	2011	2021	LEAKAGE TARGET ATTAINED	
					2011	2021
THAMES WATER UTILITIES LTD						
Upper Thames	224	262	294	328	274	306
Kennet-Reading	179	209	236	262	218	242
Slough-Wycombe-Aylesbury	165	184	202	222	189	208
Guildford	45	51	57	63	51	56
London	2125	2238	2389	2541	2074	2206
TOTAL	2738	2944	3178	3416	2806	3018
THREE VALLEYS WATER SERVICES						
Lee Valley	322	338	359	377	359	377
Colne Valley	211	230	238	248	210	219
Rickmansworth	214	234	255	275	245	264
TOTAL	747	802	852	900	814	860
NORTH SURREY WATER CO	146	154	165	181	161	177
EAST SURREY WATER CO	113	126	137	149	137	149
MID SOUTHERN WATER CO	222	265	310	362	310	362
SUTTON & DISTRICT WATER CO	65	70	73	75	73	75
REGIONAL TOTAL	4031	4361	4715	5083	4301	4641

TABLE 2.2 **PUBLIC WATER SUPPLY DEMANDS - WEEKLY PEAK (Ml/d)**

STRATEGY AREA	1991			2001			2011			2021		
	Av Dem	PF	P Dem	Av Dem	PF	P Dem	Av Dem	PF	P Dem	Av Dem	PF	P Dem
THAMES WATER UTILITIES LTD												
Upper Thames	224	1.30	291	262	1.35	354	294	1.40	412	328	1.45	476
Kennet-Reading	179	1.31	234	209	1.38	288	236	1.45	342	262	1.52	398
Slough-Wycombe-Aylesbury	165	1.32	218	184	1.41	259	202	1.50	303	222	1.59	353
Guildford	45	1.70	77	51	1.75	89	57	1.80	103	63	1.85	117
London	2125	1.10	2338	2238	1.10	2462	2389	1.10	2628	2541	1.10	2795
TOTAL	2738	1.15	3158	2944	1.17	3453	3178	1.19	3787	3416	1.21	4138
THREE VALLEYS WATER SERVICES												
Lee Valley	322	1.21	390	338	1.32	446	359	1.44	517	377	1.56	588
Colne Valley	211	1.21	255	230	1.32	304	238	1.44	343	248	1.56	387
Rickmansworth	214	1.21	259	234	1.32	309	255	1.44	367	275	1.56	429
TOTAL	747	1.21	904	802	1.32	1059	852	1.44	1277	900	1.56	1404
NORTH SURREY WATER CO	146	1.34	196	154	1.48	228	165	1.62	267	181	1.76	319
EAST SURREY WATER CO	113	1.37	155	126	1.55	195	137	1.73	237	149	1.80	268
MID SOUTHERN WATER CO	222	1.30	289	265	1.30	345	310	1.30	403	362	1.30	471
SUTTON & DISTRICT WATER CO	65	1.63	106	70	1.63	114	73	1.63	119	75	1.63	122
REGIONAL TOTAL	4031	1.19	4808	4361	1.24	5393	4715	1.28	6040	5083	1.32	6722

PF - Peak Factor P Dem - Peak Demand

2.3 Non-Public Water Supplys

An indication of the water demands for uses other than public water supply has been obtained from a record of authorised abstractions supplied by NRA Thames. The list of abstractions is recorded by catchment areas and these have been allocated to strategy areas by visual inspection.

The demands have been divided into agricultural and industrial requirements and are shown in Table 2.4. The authorised amounts are given as annual totals and to arrive at the figures in Table 2.4, which are given in Ml/d, the annual totals have been divided by 365.

The agricultural demands have been subdivided into: spray irrigation, other agricultural requirements, and fish and watercress farming. Within the industrial demands the water requirements of the power generation section have been separated as this is a large commitment. The power generation figures have been further subdivided into 'through' cooling water and "evaporative" cooling water.

The consumptive uses within the above categories are spray irrigation, general agricultural requirements and a portion of the industrial demand. Of the industrial demand about 50% is allocated to 'through' cooling for power generation or for 'washing' purposes, and a high proportion of this will be returned to the water courses.

It should be noted that a large percentage of the power generation needs and the other industrial demands within the London area are abstracted from tidal reaches of the Thames and from its tributaries.

The demand category figures given in Table 2.4 are based on licensed abstractions but none of these have taken up in full their annual authorised amount as shown below:-

TABLE 2.3 **PUBLIC WATER SUPPLY DEMANDS - SEASONAL* PEAK (Ml/d)**

STRATEGY AREA	1991			2001			2011			2021		
	Av Dem	PF	P Dem	Av Dem	PF	P Dem	Av Dem	PF	P Dem	Av Dem	PF	P Dem
THAMES WATER UTILITIES LTD												
Upper Thames	224	1.06	237	262	1.06	278	294	1.06	312	328	1.06	348
Kennet-Reading	179	1.06	190	209	1.06	222	236	1.06	250	262	1.06	278
Slough-Wycombe-Aylesbury	165	1.06	175	184	1.06	195	202	1.06	214	222	1.06	235
Guildford	45	1.06	48	51	1.06	54	57	1.06	60	63	1.06	67
London	2125	1.03	2189	2238	1.03	2305	2389	1.03	2461	2541	1.03	2617
TOTAL	2738	1.04	2839	2944	1.04	3054	3178	1.04	3297	3416	1.04	3545
THREE VALLEYS WATER SERVICES												
Lee Valley	322	1.06	341	338	1.06	358	359	1.06	381	377	1.06	400
Colne Valley	211	1.06	224	230	1.06	244	238	1.06	252	248	1.06	263
Rickmansworth	214	1.06	227	234	1.06	248	255	1.06	270	275	1.06	292
TOTAL	747	1.06	792	802	1.06	850	852	1.06	903	900	1.06	955
NORTH SURREY WATER CO	146	1.06	155	154	1.06	163	165	1.06	175	181	1.06	192
EAST SURREY WATER CO	113	1.06	120	126	1.06	134	137	1.06	145	149	1.06	158
MID SOUTHERN WATER CO	222	1.06	235	265	1.06	281	310	1.06	329	362	1.06	384
SUTTON & DISTRICT WATER CO	65	1.06	69	70	1.06	74	73	1.06	77	75	1.06	80
REGIONAL TOTAL	4031	1.04	4210	4361	1.04	4556	4715	1.04	4926	5083	1.05	5314

PF - Peak Factor P Dem - Peak Demand * Seasonal peak applies to average demand in three consecutive months of high demand.

TABLE 2.4 NON-PUBLIC WATER SUPPLY DEMANDS - AUTHORISED VOLUMES (Ml/d) (1)

STRATEGY AREA	AGRICULTURAL			INDUSTRIAL		
	(2) SPRAY IRR	OTHER AG	FISH FARM. & W.CRESS	POWER GENERATION (THRO')	POWER GENERATION (EVAP.)	(3) OTHER
THAMES WATER UTILITIES LTD						
Upper Thames	4	6	53	0	0	51
Kennet-Reading	4	5	67	144	47	70
Slough-Wycombe-Aylesbury	3	1	3	0	0	25
Guildford	1	0	4	0	0	2
London	2	0	0	11743	0	406
TOTAL	14	12	127	11887	47	554
THREE VALLEYS WATER SERVICES						
Lee Valley	6	2	11	0	0	36
Colne Valley	1	0	22	0	0	21
Rickmansworth	1	1	43	0	0	78
TOTAL	8	3	76	0	0	135
NORTH SURREY WATER CO	2	0	4	0	0	24
EAST SURREY WATER CO	1	0	0	0	0	9
MID SOUTHERN WATER CO	5	1	8	0	0	13
SUTTON & DISTRICT WATER CO.	0	0	0	0	0	4
REGIONAL TOTAL	30	16	215	11887	47	739

NOTES: (1) Authorised volumes are in cubic metres per year. Demands shown are; authorised volumes/ (365 x 1000)
(2) Figure includes winter storage for summer irrigation and irrigation of gold courses and other recreational areas
(3) Other industries are licensed for evaporative cooling but the amount is negligible (less than 0.5 Ml/d)

	Licensed Abstraction Ml/d	Actual Abstraction Ml/d	Difference Ml/d	Comment
Spray Irrigation	29	12.4	16.6	Consumptive use
Agriculture other than Spray Irrigation	16	0.8	15.2	Mixed, mainly consumptive
Fish Farming and Watercress Growing	215	3.5	211.5	Non-consumptive use
Power Generation Cooling (total)	11933	1545	10388.0	Mixed use, mostly non-consumptive
Other Industrial	739	545	194.0	Mixed use

Growth of non-public water supply has been very low over the last decade. Inspection of applications for abstraction licenses for 1988/89 and 1989/90 indicate that over these two years the requests for spray irrigation amounted to 1.1 Ml/d and for industrial purposes 2.0 Ml/d of which 'cooling' and 'washing' requirements amounted to 16.2 Ml/d. It is not expected, therefore, that the demand within the non-public water supply sector is likely to grow sufficiently to have a significant effect on the overall resource /demand balance. However, its impact could be felt locally and demands in this sector will need to be carefully monitored to allow appropriate response as they arise.

3. PRESENT RESOURCE/DEMAND BALANCE AND FUTURE DEFICITS

3.1 General

The present resource/demand and future deficits have been prepared for each strategy area on the basis of resource yield estimates made available for this study by Thames NRA, together with the present and forecast demands detailed in Chapter 2.

Resource yield figures are summarised in Table 3.1 and are the best estimates available at this time although it should be noted that they have not been prepared on a common basis. They show a present resource yield of about 4224 Ml/d rising to 4240 Ml/d by 2001. The yield estimates incorporate the phasing of existing licences.

Some resource yield estimates will decrease by 1996 in line with environmental requirements, particularly groundwater abstractions in catchments experiencing low flow conditions. Halcrow (1991) estimated the reduction at around 198 Ml/d during the national overview. However, NRA estimates of reductions amount to 16 Ml/d, 12 Ml/d and 9 Ml/d in the Misbourne, Ver and Pang catchments respectively, a total of 37 Ml/d.

Southern NRA have indicated that a reduction of up to 40 Ml/d will probably be required in the TWUL sources in the Darent Valley, and this will need to be made up by resource developments within Thames Region.

The accompanying tables of deficits (Tables 3.2, 2.2 and 3.4) have been based entirely on the above resource yields and present and forecast future demand figures covered in Chapter 2.

TABLE 3.1 **PUBLIC WATER SUPPLY YIELDS - (Ml/d)**

STRATEGY AREA	1991	2001	2011	2021
THAMES WATER UTILITIES LTD				
Upper Thames	287	287	287	287
Kennet-Reading +	185	200	200	200
Slough-Wycombe-Aylesbury *	187	179	179	179
Guildford	71	71	71	71
London ♦	1970	1930	1930	1930
TOTAL	2700	2667	2667	2667
THREE VALLEYS WATER SERVICES				
Lee Valley o	354	374	374	374
Colne Valley	229	241	241	241
Rickmansworth *	234	251	251	251
TOTAL	817	866	866	866
NORTH SURREY WATER CO	201	187	187	187
EAST SURREY WATER CO	147	147	147	147
MID SOUTHERN WATER CO	292	305	305	305
SUTTON & DISTRICT WATER CO	67	67	67	67
REGIONAL TOTAL	4224	4239	4239	4239

NOTE: Yields supplied by NRA THAMES and phased licence increases.

\+ = Yield reduction in Pang catchment in 1991,
* = Yield reduction Misbourne catchment before 1996,
♦ = Yield reduction in Darent catchment in 1996,
o = Yield reduction in Ver catchment in 1993

TABLE 3.2 PUBLIC WATER SUPPLY - SURPLUSES AND DEFICITS (Ml/d) - AVERAGE DEMANDS

STRATEGY AREA	1991			2001			2011			2021		
	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit
THAMES WATER UTILITIES LTD												
Upper Thames	287	224	63	287	262	25	287	294	-7	287	328	-41
Kennet-Reading	185	179	6	200	209	-9	200	236	-36	200	262	-62
Slough-Wycombe-Aylesbury	187	165	22	179	184	-5	179	202	-23	179	222	-43
Guildford	71	45	26	71	51	20	71	57	14	71	63	8
London	1970	2125	-155	1930	2238	-308	1930	2389	-459	1930	2541	-611
TOTAL	2700	2738	(-155)	2667	2944	(-322)	2667	3178	(-525)	2667	3416	(-757)
THREE VALLEYS WATER SERVICES												
Lee Valley	354	322	32	374	338	36	374	359	15	374	377	-3
Colne Valley	229	211	18	241	230	11	241	238	3	241	248	-7
Rickmansworth	234	214	20	251	234	17	251	255	-4	251	275	-24
TOTAL	817	747	(+70)	866	802	(+64)	866	852	(14)	866	900	(-34)
NORTH SURREY WATER CO	201	146	55	187	154	33	187	165	22	187	181	6
EAST SURREY WATER CO	147	113	34	147	126	21	147	137	10	147	149	-2
MID SOUTHERN WATER CO	292	222	70	305	265	40	305	310	-5	305	362	-57
SUTTON & DISTRICT WATER CO	67	65	2	67	70	-3	67	73	-6	67	75	-8
REGIONAL TOTAL	4224	4031	(-155)	4239	4361	(-325)	4239	4715	(-536)	4239	5083	(-858)

TABLE 3.3 **PUBLIC WATER SUPPLY - SURPLUSES AND DEFICITS (Ml/d) - SEASONAL PEAK DEMANDS**

STRATEGY AREA	1991			2001			2011			2021		
	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit
THAMES WATER UTILITIES LTD												
Upper Thames	287	237	50	287	278	9	287	312	-25	287	348	-61
Kennet-Reading	185	190	-5	200	222	-22	200	250	-50	200	278	-78
Slough-Wycombe-Aylesbury	187	175	12	179	195	-16	179	214	-35	179	235	-56
Guildford	71	48	23	71	54	17	71	60	11	71	67	4
London	1970	2189	-219	1930	2305	-375	1930	2461	-531	1930	2617	-687
TOTAL	2700	2839	(-224)	2667	3054	(-413)	2667	3297	(-641)	2667	3545	(-822)
THREE VALLEYS WATER SERVICES												
Lee Valley	354	341	13	374	358	16	374	381	-7	374	400	-26
Colne Valley	229	224	5	241	244	-3	241	252	-11	241	263	-22
Rickmansworth	234	227	7	251	248	3	251	270	-19	251	292	-41
TOTAL	817	792	(+25)	866	850	(+16)	866	903	(-37)	866	955	(-89)
NORTH SURREY WATER CO	201	155	46	187	163	24	187	175	12	187	192	-5
EAST SURREY WATER CO	147	120	27	147	134	13	147	145	2	147	158	-11
MID SOUTHERN WATER CO	292	235	57	305	281	24	305	329	-24	305	384	-79
SUTTON & DISTRICT WATER CO	67	69	-2	67	74	-7	67	77	-10	67	80	-13
REGIONAL TOTAL	4224	4210	(-226)	4239	4556	(-420)	4239	4926	(-717)	4239	5314	(-1079)

TABLE 3.4 PUBLIC WATER SUPPLY - SURPLUSES AND DEFICITS (Ml/d) - ADDITIONAL LEAKAGE CONTROL

STRATEGY AREA	AVERAGE DEMANDS						SEASONAL DEMANDS					
	2011			20211			2011			2021		
	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit	Yield	Demand	Surplus/ Deficit
THAMES WATER UTILITIES LTD												
Upper Thames	287	274	13	287	306	-19	287	290	-3	287	324	-37
Kennet-Reading	200	218	-18	200	242	-42	200	231	-31	200	257	-57
Slough-Wycombe-Aylesbury	179	189	-10	179	208	-29	179	200	-21	179	220	-41
Guildford	71	51	20	71	56	15	71	54	17	71	59	12
London	1930	2074	-144	1930	2206	-276	1930	2136	-206	1930	2272	-342
TOTAL	2667	2806	(-172)	2667	3018	(-366)	2667	2911	(-261)	2667	3132	(-477)
THREE VALLEYS WATER SERVICES												
Lee Valley	374	359	15	374	377	-3	374	381	-7	374	400	-26
Colne Valley	241	210	31	241	219	22	241	223	18	241	232	9
Rickmansworth	251	245	6	251	264	-13	251	260	-9	251	280	-29
TOTAL	866	814	(+52)	866	860	(+6)	866	864	(+2)	866	912	(-46)
NORTH SURREY WATER CO	187	161	26	187	177	10	187	171	16	187	188	-1
EAST SURREY WATER CO	147	137	10	147	149	-2	147	145	2	147	158	-11
MID SOUTHERN WATER CO	305	310	-5	305	362	-57	305	329	-24	305	384	-79
SUTTON & DISTRICT WATER CO	67	73	-6	67	75	-8	67	77	-10	67	80	-13
REGIONAL TOTAL	4239	4301	(-183)	4239	4641	(-433)	4239	4497	(-295)	4239	4854	(-627)

The deficits for 1991 and for subsequent 10 yearly intervals to 2021 based on forecast annual average demand for public water supplies are presented in Table 3.2. The table assumes leakage and demand management continuing at approximately current levels.

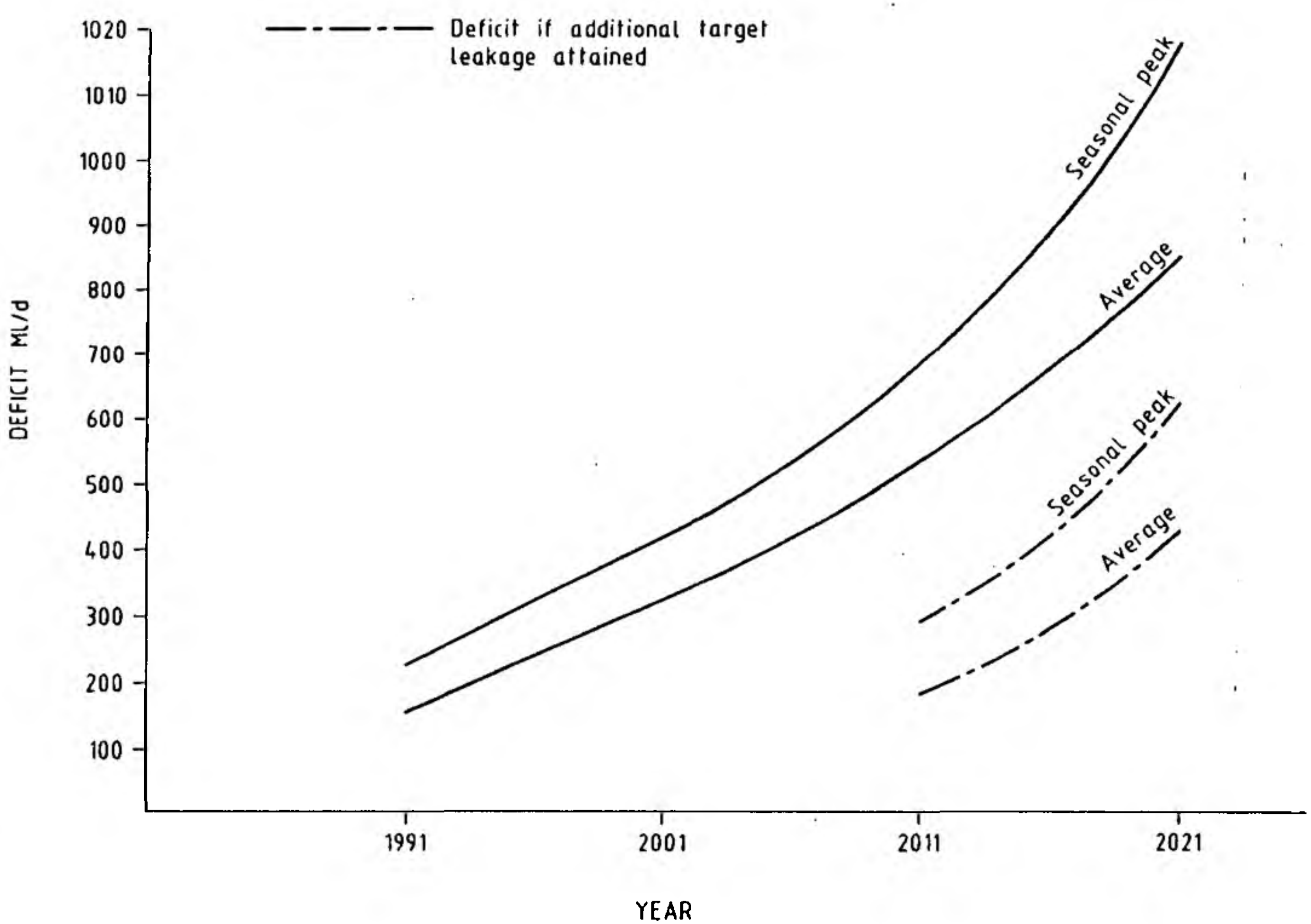
Table 3.3 differs from Table 3.2 in that deficits have been assessed on 3 month summer seasonal demands rather than annual average. The seasonal demand have been estimated at 6% above annual, except for the London supply area of Thames Water where 3% in excess of annual average better reflects the variation. Yield figures in Table 3.3. are as in Table 3.2.

The deficits shown in Table 3.4 take account of possible reduced demands arising from lower levels of leakage losses (and perhaps improved demand management) of between 20% and 12% that may be achieved by 2011 and 2021, as proposed by the water undertakers. The table gives the deficits for both these years related to average annual and summer seasonal demands.

Deficits for both annual and summer seasonal demands and with prevailing and target levels of leakage reduction, are shown graphically in Figure 3.1

3.2 Present Resource/Demand Balance

The tables show that only in the London supply area of TWUL is there a prevailing deficit of resource output capacity to demand. This is 155 Ml/d on average annual demand and 226 Ml/d on summer seasonal. Demands have been met in practice by overdrawing of sources in relation to their assessed reliable yield. No allowance has been made for off-setting the London deficit by assuming re-allocating surpluses elsewhere in the region. This would require agreements that may prove difficult to negotiate between competing supply companies. In any case only those other supply areas in present surplus which also use the lower Thames and/or the Lee would be in any practicable position to help offset London's deficit.



PUBLIC WATER SUPPLY
TOTAL DEFICIT TO 2021

FIGURE 3.1

3.3 Future Deficits

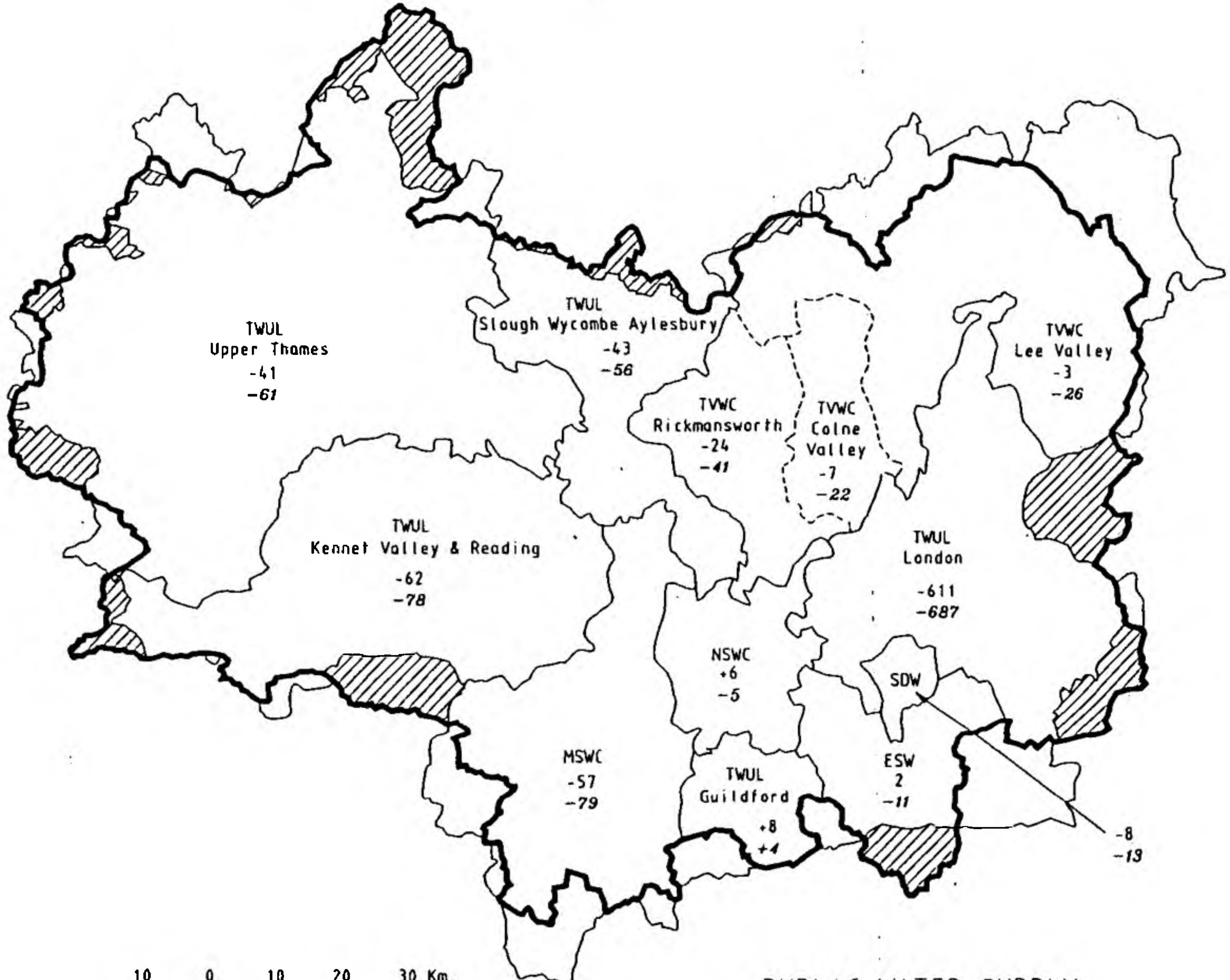
From 2001 onwards allowance has been made for additional source yield to be provided by approved new sources and also by planned phasing of licences. The only deficit of strategic significance in 2001 remains the London strategy area with 308 Ml/d deficit on annual average demand and 375 Ml/d for summer season demand levels, with small deficits in the Kennet, Reading and Slough-Wycombe-Aylesbury areas. By 2011 and 2021, the remaining supply areas of Thames Water, apart from Guildford, will run into deficits.

The regional deficits as a whole in 2011 are estimated as 536 Ml/d on average annual and 712 Ml/d on summer season levels, reduced to 183 and 295 Ml/d respectively if company additional target levels of leakage reduction to between 12% and 20% are achieved. Projections to 2021 show further increasing deficits as set out in the tables, with a greatest deficit of 1079 Ml/d related to summer demands and prevailing leakage levels.

The deficits and surpluses forecast for 2021 by strategy area for both average demand and seasonal demand are illustrated in Figure 3.2. Figure 3.3 presents the 2021 situation for the case where the various company leakage targets are attained, showing the significance of this factor on deficit forecasts.

3.4 Resource Development Requirements

The deficit forecasts suggest that initial planning with consideration of development options for an aggregate of new resources for public supplies with a yield capacity of up to 1000 Ml/d would be of the right order while limiting the subsequent stages of development planning and scheme promotion for the time being to about 500 Ml/d additional yield regionally. This will enable phasing of source development to take account of enhancement or reduction in the planning demand target over the next 10-15 years as demand forecasts for 2011 and 2021 are refined.

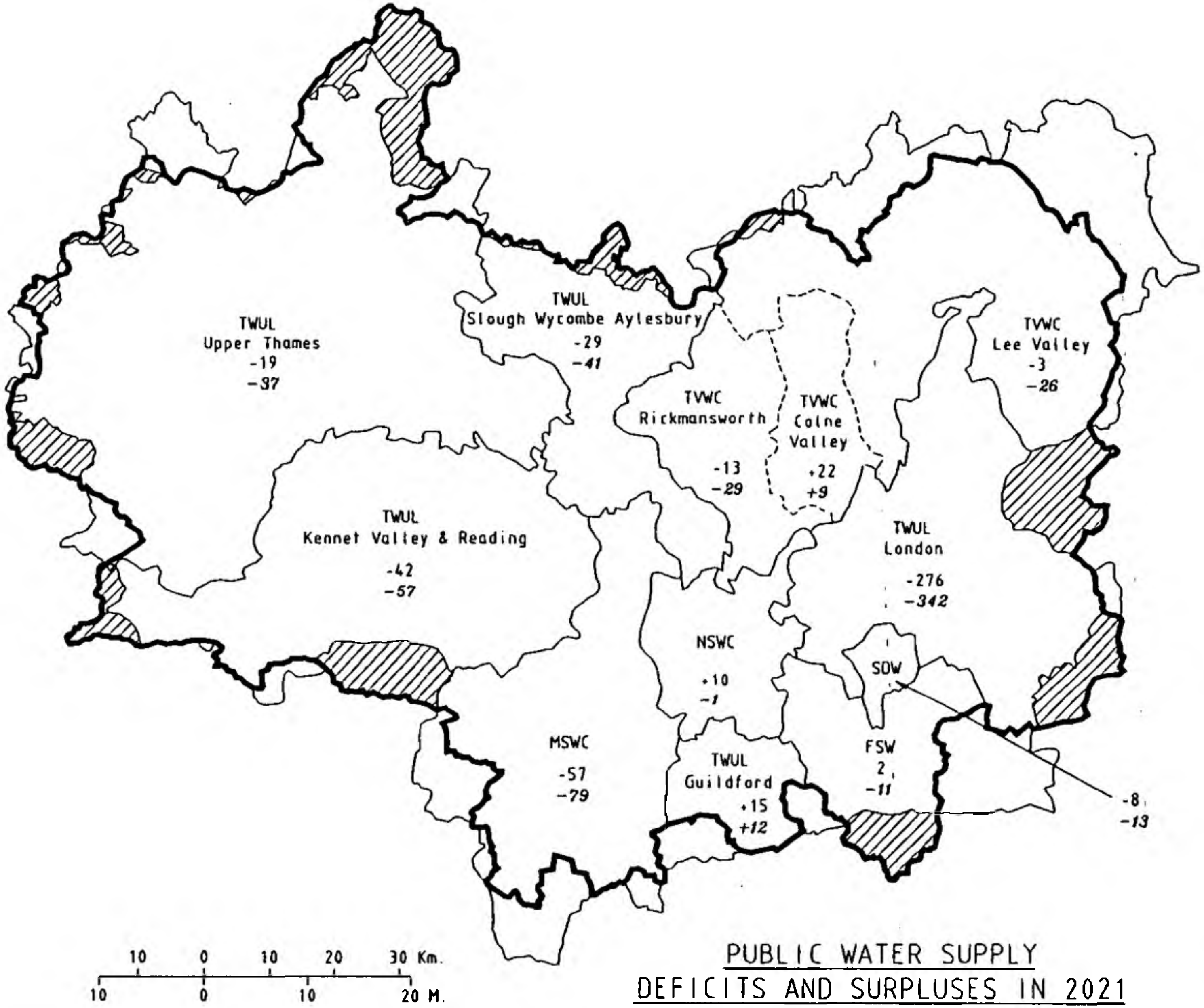


LEGEND
Deficit -
Surplus +
Average Demand -41
Seasonal Peak *-61*
Total Deficit 2021
Average = 852ml/d
Seasonal Peak = 1018ml/d

10 0 10 20 30 Km.
10 0 10 20 M.

PUBLIC WATER SUPPLY
DEFICITS AND SURPLUSES IN 2021

Figure 3.2



LEGEND
Deficit -
Surplus +
Average Demand -41
Seasonal Peak *-61*
Total Deficit 2021
Average = 414ml/d
Seasonal Peak = 590ml/d

PUBLIC WATER SUPPLY
DEFICITS AND SURPLUSES IN 2021
(WITH ADDITIONAL LEAKAGE CONTROL)

Figure 3.3

4. BROAD REVIEW OF DEVELOPMENT OPTIONS

4.1 General

This chapter reviews the range of water resources development options that could be available for meeting the potential deficit of present source output capacity or yield in relation to future demands to 2021 as identified in the previous chapter.

Influencing the future deficit by reduction of total abstracted demand on sources by Demand Management, such as by charging for domestic supplies (and sewerage) according to metered consumption and by improved leakage control is not regarded as a development option within the definition used in this study. Instead it is regarded as an important factor on the demand side of the resources/demand balance.

Water resources development in Thames region is heavily constrained for the reasons summarised in Chapter 1. In particular no further surface water abstraction would be permissible on a continuous basis and this would necessitate storage for continuous reliable supplies. Furthermore groundwater abstraction, already heavily developed in the region, has only limited additional potential on account of the adverse effects on river base flow in many instances.

With these factors in mind, the potential options considered in the study were:

- Reservoir storage in Thames region including enlargement of existing reservoirs.

- Thames-side groundwater development in middle Thames catchment

- London Basin groundwater including Artificial Recharge and Conjunctive Use.

- Use of gravel workings for storage.

- Re-use of effluents presently discharged to tidal Thames estuary.

- Freshwater storage in tidal Thames estuary

- Transfers from river Severn to Thames including use of canals for conveying water.

- Transfers from Anglian region to Thames catchment including onward transfers from river Trent.

- Transfers from further afield including from Wales (River Wye) Northumbria (Kielder) and Scotland.

- Desalination of sea water

The foregoing options have been examined in broad terms in relation to technical feasibility, yield, cost and potential environmental impact. From this broad initial review of options, a short list of the more promising potential developments has been drawn up. These are described in more detail in the next two chapters. Sequential combinations of these short listed schemes have been included in alternative scenarios or programmes of resource development to meet forecast future deficits over the next 30 years or so to the 2021 planning horizon, as described in Chapter 7.

4.2 Reservoir Storage in Thames Catchment

4.2.1 General

The potential for further reservoir storage in the Thames region is heavily conditioned by topographical, geological, land use, demographic, development planning, and environmental/ecological considerations. It is also influenced by the high present level of reservoir development. This gives rise to "diminishing returns" from storage in relation to yield and limits the choice of remaining sites, which in practice must be off-river, filled by pumping rather than impounded by gravity.

4.2.2 Reservoir at Abingdon/Drayton

Many potential new reservoir sites have been examined in the catchment over the years, including many on an objective and comparative basis, prior to this study, on behalf of TWUL. As a result, TWUL have identified a site at Drayton, south-west of Abingdon, as best meeting numerous conditions and constraints for a new major surface reservoir in the Thames catchment and meeting public supply requirements in the Company's area, especially in London and in Upper Thames.

The purpose of this present study has not been to review this selection and assessment of reservoir sites or "second guess" the choice of Drayton/Abingdon as the preferred site for which to obtain powers. However, we are not immediately aware of factors that would rule out this proposal, subject to appropriate conditions, or aware of alternative sites for similar size of storage that would be preferable overall. For these reasons and as agreed with Thames NRA, we have assumed that Abingdon is currently the preferred new reservoir site, and have adopted it as the representative option of this category of resource development. Moreover as this proposal is being worked up by TWUL for a likely scheme promotion, its leading particulars of yield, cost, land take and environmental impact make a useful yardstick against which to compare the other options in this review. Further summarised particulars and assumptions as identified to date are set out in Chapter 5.

4.2.3 Redevelopment of Staines Reservoirs

Thames Water are also continuing their examination of the feasibility of enlarging the present storage at Staines North and South reservoirs, and possibly to others in the Lower Thames group. We have not independently assessed the feasibility of this proposal, but have broadly assessed costs and have included it as a component of one of the development scenarios. To do this, we have made assumptions as to additional storage and yield that may result, and have recognised that the loss of present yield during reconstruction and enlargement would present problems, including those of timing, it being imperative to carry out this work after a large additional tranche of source capacity has become available and while spare capacity exists. This option is referred to again in Chapter 5.

4.2.4 Reservoir at Waddesdon

The option for transfers from Anglian region include the possibility of a transfer route to the Thame tributary in Buckinghamshire. According to transfer arrangements, this may well entail the need for a comparatively small reservoir in the upper Thame catchment to balance intermittent transfers and augmentation releases. A potentially suitable site for this option is in a shallow valley near Waddesdon, west of Aylesbury. The site was one identified in the Water Resources Board studies in the 1960's and 1970's, but the storage now contemplated would be appreciably smaller. This is also referred to again in Chapter 5, in the context of Anglian-Thames transfers.

4.3 Thames-side Groundwater

Because of the levels of present groundwater abstraction which already cause depletion or even cessation of base flow in some tributary streams, we accept the view of Thames NRA that further substantial groundwater abstraction would not be environmentally feasible in the greater part of the mainly unconfined Chalk and Oolite aquifers in the middle and upper parts of the catchment. Any further abstraction, if at all in those areas, would have to be restricted to relatively small quantities typically for direct industrial supplies.

The only locations where larger abstractions for public supply purposes may be permissible are along the main Thames valley corridor in its middle reaches from the Goring Gap downstream through Reading and Henley to

Marlow. Indeed a start on this option has already been made with the licensing recently of a major new Chalk groundwater source at Gatehampton near Goring for up to 55 Ml/d for Thames Water.

There seems little or no further opportunity for further single site sources of this size; a number of Thames-side sites to be developed in the above area are assumed to yield an aggregate of 70 Ml/d, as discussed in Chapter 5.

4.4 London Basin Groundwater

Consideration of development of groundwater in the greater London area, or the London Basin, has been separated from the rest of the region in this study because very different circumstances and hence opportunities apply. The water bearing Chalk, and overlying Basal Sands of the Tertiary deposits, form a single aquifer unit confined by a thick overlying layer of highly impermeable London Clay which precludes direct natural recharge from the surface within the basin. Instead the aquifer is recharged from its unconfined outcrop on the surrounding high ground of the Chilterns, North Downs and in Berkshire. For about a century until the Second World War, abstraction in central London far exceeded the slow replenishment from the surrounding outcrop, and caused extensive long-term lowering of water levels in the confined basin. From the 1950's onwards groundwater abstraction for direct supplies in the basin has greatly reduced, causing water levels to rise again towards their early 19th century condition and becoming a threat to deep foundations, tunnels, etc, constructed while water levels were depressed. There is thus a positive need and advantage in keeping water levels in the confined area lowered and controlled. In doing so it is possible to take advantage for supply of the water that is pumped. This amount would be quite limited, however, if balanced against the remote natural recharge and if carried out on a continuous uniform basis.

The approach being investigated and which we believe to be a very attractive option is to operate the London Basin groundwater by augmenting natural recharge with artificial recharge particularly by treated mains water when and where available, for example, in the Haringey/Enfield and Lee Valley areas of North London during non-drought periods, and using the groundwater source conjunctively with surface sources. The recharging with temporarily surplus treated water is part of this conjunctive use which also involves resting the groundwater for much of the time when associated surface supplies are adequate, but switching to groundwater say one summer in 8 or 10 on average when drought conditions limit the surface water output, and when the large natural groundwater storage could be drawn upon to make good the total requirement.

Water levels would be allowed to recover up to the controlled maximum level by resting between drought periods. In South London where opportunities for artificial recharge and available natural storage for the purposes are limited, this would seem the most effective means of developing the source.

We can only make a broad general estimate of the infrastructure needed and of the overall cost of such a scheme, but this together with updating previous estimates of similar scale of proposals suggest that it would be very competitive on cost grounds with other options. The scheme would be relatively quick to develop and bring into use. There would be nett environmental benefit resulting from the control of rising water levels. For these reasons we have included this proposal as one of the common base options in the scenarios of source development. It is assumed from the assessments made that an additional resource value of 230 Ml/d would be available for the supply to London when operated intermittently and conjunctively with surface sources as described above. Although there will be water quality variations in supply in London as the proportion of groundwater changes, these should not be excessive and treatment and blending should be well able to overcome this difficulty. This option is described further in Chapter 5.

4.5 Use of Gravel Pits for Storage

This option has been mooted in the past as a relatively cheap and environmentally acceptable means of providing surface storage as an alternative to purpose built reservoirs and resulting in saving on use of undeveloped land.

We have accordingly examined this option in some detail, particularly in the more westerly or upstream parts of the catchment. Here there are extensive worked-out flooded gravel workings and more extraction is expected to take place in future.

The constraints on use of gravel pits for water storage are chiefly:

(i) most of those already worked out have been converted to much valued wildlife habitats and/or water based recreational centres, there would be strong resistance to a change or sharing of use involving fluctuating water levels;

(ii) water storage use requires a reasonable degree of watertightness in relation to the adjacent river, stream or watercourse; this is generally not available naturally, especially through the gravel sides, and to provide it would involve lining or curtain grouting;

(iii) the depth of worked out gravel pits is usually not great, depending upon the depth of gravel occurring above the impermeable base; this severely limits the volume of storage available for a given water area.

The prospects of using possible future large gravel workings for water storage appear better than changing the use of existing ones. This post-extraction use would need to be identified and agreed beforehand, and the work planned accordingly. Once the gravel had been extracted the volume of storage could be increased either by excavation of the underlying strata or by embanking the perimeter. A possible competing use could be landfill of waste material; environmentally, waste storage would likely be seen as preferable.

Whilst in general terms gravel workings may be regarded as a direct alternative to purpose built reservoirs, the volume of storage would typically be about an order of magnitude less. However, we do see a very attractive role for gravel pit storage in association with transfers of water from the river Severn. Used in this way it could provide limited but most valuable storage for balancing variations in quantity and for quality blending. This option has accordingly been short-listed in this context and more details are given in Chapter 5.

4.6 Re-use of Effluent Discharged to Tidal Thames

The bulk of the potable water consumed in the London area is abstracted from the River Thames above the tidal limit at Teddington weir, and from the non-tidal reaches of the River Lee. Virtually all of this water is brought after use to sewage treatment plants which discharge the effluent after treatment to the tidal reaches of the Thames and Lee to be lost to the freshwater system.

If part of this discharge could be diverted, given additional treatment and pumped to discharge upstream within the freshwater non-tidal river system, it would allow abstraction of similar magnitude from the freshwater resources of the catchment.

From the several possibilities for developing this option, two in particular have been assessed in this study as being prima facie the most promising. The view has been taken that to obtain the most benefit from effluent re-use it is necessary for it to enhance, directly or indirectly, potable public supplies as opposed to meeting the much more limited requirements for lower quality industrial supplies (which are already met and can continue to be met from the tidal estuary).

The effluent re-use options considered are:

(i) Divert part of the flow from Mogden STW which currently discharges to the Thames about 6km downstream of the tidal limit at Teddington Weir. At critical periods of low river flow, tertiary treated effluent would be diverted and pumped to discharge to the non-tidal Thames about 9 km upstream of Teddington. The diverted effluent would thus augment the residual flow in the reach from Sunbury to Teddington, allowing an equivalent additional amount of the natural flow further upstream to be abstracted from the river into the lower Thames reservoirs for supply.

(ii) Divert part of the flow from Deephams STW in the Lee Valley, currently discharging to the river below the supply intakes, to the Lee Valley reservoirs. The diverted effluent, after additional tertiary treatment, would be pumped to discharge either directly into one of the water supply reservoirs or to the river Lee upstream of the intakes so that advantage can be taken of the augmented flow at critical periods.

One of the most difficult questions in considering re-use of effluent to benefit potable supplies is that relating to public perception and possible rejection of a scheme that deliberately increases the treated sewage element of raw water supplies destined for potable consumption. Largely for that reason the residual flow replacement option holds considerable attraction. The effluent used would be treated to a high standard (appreciably higher than present requirements for the tidal discharge) and from a chemical quality stand-point would not cause a deterioration of the residual river flow quality. In the Lee Valley residual flow replacement would not be an available option. There the diverted treated effluent would be part of the replenishing inflow to at least one of the reservoirs. However it would only form a small proportion of the total quantity with ample storage for blending and retention.

Technically and economically re-use of effluent otherwise lost to the water resources system at critical periods has much to commend it, and it is therefore one of the options short-listed and described in more detail in Chapter 5.

4.7 Freshwater Storage in Tidal Thames Estuary

4.7.1 Use of Thames Barrier

For about the last ten years consideration has been given to using the Thames Barrier as a means of providing fresh water storage on the Thames. Between 1980 and 1982 three desk studies were carried out on this proposal and the conclusions were summarised internally by Thames Water Authority in 1985.

The benefits and disbenefits summarised indicated that apart from the possible, and by no means certain, benefit of creating a resource of up to 200 Ml/d the only other benefits will be to:-

- inundation of mud flats would give an aesthetic benefit in respect of recreation and amenity, while greater minimum water depth would allow water based recreational activities irrespective of tide;
- irrespective of tide, navigation would be possible upstream of Woolwich with a resulting benefit to the boat operating trade;
- fisheries may be improved.

The disbenefits of the proposed use of the barrage, as listed in the 1985 summary report, far outweigh the benefits, as follows:-

- a rise in groundwater levels in the vicinity of the rivers could affect stability of buildings and cause problems to underground services and the underground railway;

- siltation patterns would change both upstream and downstream of the barrage with increased dredging problems;

- water quality would be affected and it may be necessary to divert the flow from sewage treatment works and storm outfalls to discharge downstream of the barrage;

- significant ecological impacts, including effects on Syon Park SSSI, would result due to changes in salinity and reduction in water quality;

- even with a lock at the barrier, free access for navigation would be denied and boats which travel upstream with the tide would lose this advantage.

- the character of the river would change and the mudflats below Richmond would be lost, affecting fishing at low tide;

- risk of flooding would be increased;

- significant legal drawbacks would need to be overcome with the Barrier Act amended to allow a changed use. The range of public and private bodies affected by the change would be extensive and it is thought that opposition would be great.

The above arguments, particularly those relating to legal aspects, also apply, albeit to a lesser extent, should a new control structure be considered upstream in a less used and narrower part of the river.

Because of the overwhelming disbenefits associated with this option and the uncertainty of the benefit of yield, it is considered unjustified to seriously consider the option further in this study.

4.7.2 Downstream of Thames Barrier

Downstream of the barrier, any such storage would have to leave a largely unimpeded tidal channel to avoid increasing dangerous threats of flooding both as tidal surges from the sea and from build up of freshwater from upstream. This constitutes such a major constraint on bunded storage within the tidal channel that we must agree with earlier views that this option is infeasible.

This leaves an option of off-channel storage. Here the problem is to find a site where there is little or no present development, in order to minimise disturbance. This in turn would mean in practise a site well down the estuary, at least downstream of Rainham and Erith, and probably downstream of Tilbury and Gravesend. A site so far down the estuary would give rise to very high costs of conveying the fresh water both from West of London into storage, as well as back from the reservoir to the London distribution system where it would be mostly needed.

These considerations suggest that the unit cost of storage, given that a technically feasible and acceptable site could be found, would be very high, perhaps some 2 or 3 times that of up-river storage. Furthermore the benefits for river management as well as for water resources and supplies generally within the Thames region would be more limited. We do not therefore propose to include this among the short-listed options for more detailed appraisal in this study.

4.8 Transfers from River Severn to Thames

Transfers from the River Severn to the upper Thames is the transfer option from another region that has attracted most attention and study in the past. It was a key element of the preferred strategy put forward by the Water Resources Board (WRB) in their national planning report published in 1974, and was examined in much greater detail by the former Central Water Planning Unit (CWPU) in a five year study reported on in 1980. This option is considered afresh in the present study in the light of current circumstances and revised future needs. Because of the high level of water resource development already reached in Thames region, the concept of augmenting available resources by transfers from outside the region remains an attractive option, given the ongoing need for more water.

The previous studies had assumed that storage to support the transfers would be provided in the donor catchments, viz Severn and/or Wye. This is true both of the turn of the century proposals for direct supply from Wales to London by aqueduct, and of the WRB/CWPU studies referred to above based river to river transfers. There is now no evident need for additional large scale river regulating storage in the Wye and Severn to meet demands in those regions. This would mean that any such storage would have to be justified and provided mainly or entirely to support the transfers to Thames. Whilst this remains a theoretical option, attention has instead concentrated in this study on examining the possibilities of transferring water from the lower Severn within the prevailing river regulation regime on that river and providing the necessary balancing storage in the Thames catchment instead. This option would have several advantages for Thames region, notably:

- it would obviate the need for remote storage at Craig Goch (or equivalent) and associated works;
- it would eliminate further regulation losses on the Severn which could be a significant cause of inefficiency in the extended system;
- storage in the Thames catchment would provide for blending with Thames derived water with likely water quality benefits;
- storage in Thames would have substantial management advantages for promotion, financing and operational control.

This option would mean that while water would be available for transfer for much of the time it is needed, there would not be sufficient excess above any likely prescribed residual flow on the lower Severn to permit abstractions during periods of very low flow.

This remains an attractive option when operated in association with existing and possible further storage in Thames catchment, including worked out or new gravel workings. Where still relevant we have adopted or adapted assumptions, conclusions and recommendation from the CWPU study. Further details of this short-listed option are given in Chapter 6.

That study included detailed desk assessments of the alternatives for the intake location on the lower Severn, the point of discharge in the Thames catchment, and the routing and means of transmitting the water between. Essentially we have adopted assumptions on these factors that were shown as most favourable in the CWPU report; these are set out in Chapter 6.

The CWPU considered in some detail and rejected the concept of using canals for the transfer. Their consideration and conclusion on this were summarised in pp48 and 49 of their 1980 report. We take the view that circumstances and assumptions have not significantly changed in relation to this since then, and we feel justified in following their conclusion that use of either a new multi-purpose canal or use of existing ones including the derelict Sapperton tunnel would not be a feasible or economic solution. We have however, examined further the possibility of partially substituting a tunnel instead of pipe aqueduct through the high ground, both to reduce pumping lift and to reduce environmental effects, especially during construction.

Further details of this short-listed Severn-Thames transfer options are given in Chapter 6.

4.9 Transfers from Anglian Region to Thames

This is the second of the two main transfers from outside the region into Thames considered in this study and has a number of sub-options. There are existing transfers between the two regions on a comparatively limited scale, including notably:

- a 70 Ml/d treated water bulk supply from Anglian Water's Grafham reservoir source to Three Valleys WC, with present provision for this to be increased to 90 and later to 136 Ml/d.
- a 90 Ml/d bulk supply in the opposite direction further south from Thames region to Essex Water Co. at Chigwell in the Roding Valley on the west of their supply area.

Transfers from Anglian at the Thames regional boundary would be geographically closer to London and the other main population centres in Thames. However, Anglian is a notably dry region, and although it has some surplus output from the major resources built in the region since the 1950's, notably Grafham and Rutland Waters (pump filled reservoirs), this surplus is not expected to continue for more than a decade, after which Anglian region would itself need more resources. Possible options include new reservoir storage to be filled through the Ely-Ouse-Essex transfer link, and/or transfers from the River Trent into the Lincolnshire part of Anglian region, to support and augment transfers south within Anglian. The opportunity may therefore arise whereby sufficient additional water could be provided to allow for transfers onwards into Thames. The assumption in considering this option therefore is that any future transfer from Anglian into Thames would be part of and additional to development and transmission of resources for Anglian region itself. The means and conditions of making the water available within Anglian region, including for any Thames transfers, are the subject of a separate study and assessment by Anglian NRA.

The options for Thames considered in this present study are:

- treated supplies from Grafham Water to Three Valleys over and above the presently intended maximum of 136 Ml/d;
- phasing out the 90 M/ld supply from Thames to Essex, replacing it with water from Anglian regions, and redeploying the Thames supply within the eastern part of the Thames region.

- intermittent transfers of river augmentation in Thames region,
  - (a) to the Thame tributary near Aylesbury, which would be able to augment flows in the Thames downstream of the Thame/Thames confluence between Abingdon and Wallingford, and/or
  - (b) to the river Stort tributary of the River Lee, having a more limited application for meeting deficits without reallocation of supplies.

The outline of specific options considered and costed including the marginal additional costs into and within Anglian region to provide for these transfers to Thames region are set out for this short-listed option in Chapter 6.

4.10 Transfers from Further Afield

4.10.1 General

Those considered are:

- River Wye
- Kielder Reservoir and regulated rivers in Northumbria
- East coast rivers in Scotland

In order to make such distant imports even remotely viable, it is necessary to have a reliable and readily available source of good quality water so that works for storage and treatment and hence costs at source are minimal to compensate for the high cost of transmission. This is largely true of Kielder and Scotland, but not of the Wye. However, as the latter has been considered in the past, particularly in the Craig Goch proposal, it was considered appropriate to look afresh at this option.

On the other hand there seems no need or merit in looking at options for imports from Wessex and Southern Regions, the remaining two bordering Thames. They have no surplus supplies to offer, the costs and problems of developing further resources are of a similar order as in Thames, and they are expected to have a need in future for any resources that may be available.

4.10.2 Transfer from River Wye to Thames

The possibility of transfers from the river Wye to the upper Thames has been raised, and two basic scenarios present themselves.

Transfers supported by Wye storage

The first is the use of large regulating storage in the upper Wye catchment to augment flows and hence support additional downstream abstractions.

This possibility has been examined extensively in the past; initially as part of the Craig Goch scheme study, 1974-81, and thereafter as part of the promotion in 1978 of the Welsh WA scheme for abstraction from the lower Wye at Monmouth. With there being no evident need otherwise for major additional strategic storage in the Wye (or Severn) it has been considered unnecessary to pursue this option further.

Run of River Transfers

The second scenario is to abstract from the lower Wye without further flow augmentation, that is, at those times when flows are above a prescribed minimum, balanced by storage in the Thames catchment. This is the parallel situation to that being considered in the present study for transfers from the lower Severn.

For appraisal of this option it is necessary to consider the frequency of low flows in the Wye, potential abstraction points, likely associated residual flows, routes including length and head lift for transfers to the upper Thames, and water quality aspects.

The two most relevant gauging stations on the Wye are at Belmont near Hereford and at Redbrook, downstream of Monmouth and close to the tidal limit. Redbrook may be regarded as the equivalent of Haw Bridge on the Severn, while Belmont is in a corresponding location to Bewdley. From a summary of flows in the Hydrological Data UK 1981-85, it is apparent that the Wye is a more flashy river than the Severn, with low flows not so well maintained.

The tidal limit location of the Wye is not nearly so conveniently placed for transfers to the Thames as that of the Severn. The high ground of the Forest of Dean lies immediately to the east of the Wye downstream of Monmouth, directly in the line of any transfer route to the upper Thames. In practice therefore the most convenient location for abstraction for Thames transfers would appear to be in the vicinity of Ross-on-Wye, ideally just upstream of the town. Flows at Ross are about the mean of those at Belmont upstream and Redbrook downstream. It is assumed for present purposes therefore that the minimum monthly flow at Ross is about 370 Ml/d and the 95%le flow is 760 Ml/d. It would be prudent to assume that the prescribed residual flow for any large abstraction at Ross would be of the order or even more than the latter flow, to avoid derogation of existing water supply abstractions at Lydbrook and Monmouth and of residual flows downstream of Monmouth. This reach is justifiably highly prized scenically, and furthermore riparian interests, particularly for salmon fisheries and fishing, would seek to ensure that substantial and variable residual flows are adequately safeguarded. Mean flows at Ross appear to be some 25% less than the Severn flows at Deerhurst.

With an abstraction point near Ross, it would be possible to route a transfer aqueduct to the Thames due eastwards to cross the Severn between Ashleworth and Gloucester and pick up route 4 of the CWPU Severn-Thames study near Staverton west of Cheltenham. Under the most favourable assumptions this would require a transfer aqueduct of at least 23 km net additional length (45% extra) compared with that from the Deerhurst intake proposed on the Severn.

The level of the river Wye at Ross is about 30 m AOD, compared with about 6 m at Deerhurst. However the most favourable crossing point between the Wye and Severn valleys east of Ross is at about 110 m AOD. Thus there are no pumping head advantages to set against the appreciably greater distance to transfer the water.

The general river quality of the Wye particularly upstream of Ross is higher than that of the Severn at Deerhurst, (1A compared with 1B in the 1985 River Quality Survey) and carries less residuals of industrial effluent. However the Severn river water quality is regarded as acceptable for transfers to the Thames, so the slightly higher quality of Wye water is not such as to justify the appreciable additional works and costs that a transfer from the Wye would entail.

Compared to the Severn transfer option, the combination of the much smaller quantities available for transfer and the longer periods when no water would be available without additional regulating storage for the Wye, together with the appreciably longer and more costly transfer route, would appear to rule out the Wye transfer option from further consideration.

4.10.3 Imports from Northumbria (Kielder) by River and Aqueduct

Keilder reservoir regulating the rivers Tyne, Wear and Tees probably constitutes the largest single block of surplus water resource capacity in England and Wales. Hence the viability of using this supply to meet demands in the hard pressed south-east of England, including Thames merits examination.

The problem lies in the high costs of transmission of large volumes of water over long distances unless river flows can be harnessed for the purpose. In this case, rivers could be of help for only a small part of the total distance, principally down the Tyne and in Yorkshire. The system of transmission would have to be extended from the present end point on the Tees into the Yorkshire river system. Further onward transmission thence to south of the

Humber and on into the north of the Anglian region would constitute very significant costs over and above those for conveying Trent water to Thames. This apart from inevitable river regulation losses over this distance would make the Keilder option quite uncompetitive.

4.10.4 Imports from Northumbria or Scotland by Sea

A further option considered was to convey fresh water by sea - either from the middle reaches of the Tyne at Riding Mill regulated by Kielder, or from an east coast Scottish river with a good navigable estuary such as the Forth or Tay. These latter, although more distant than the Tyne would probably allow easier access for leading the fresh water for sending by sea. We have found it difficult to make an independent estimate of costs of conveying fresh water by sea. We believe that the potentially cheapest (although still expensive) means would be by towing butyl or other toughened plastic drogues on the surface of the sea behind ocean going tugs. The national overview of water resources options put sea borne conveyance of fresh water as appreciably the most expensive of all options. This was based on use of converted oil tankers. Although it is thought that those costs could be appreciably reduced, the eventual cost would still make this economically non-viable and there seems few compensating advantages for bringing water so far.

We conclude therefore that none of these options for distant transfers into Thames from further than Severn Trent and Anglian regions offer viable solutions with clear advantages over shorter transfers and we do not include them in the short-list for further appraisal.

4.11 Desalination of Sea Water

Desalination is easily the most energy intensive of all the resources options for obtaining potable fresh water. This is true both of distillation and membrane methods.

Thermal processes for potable water production from sea water are generally not practicable within the Thames area due to the relatively small-extent of unpolluted costal zone which is available for location of seawater intakes, and which is close enough to an existing power station where waste heat may be available for its operations.

Reverse osmosis treatment of seawater or estuarine flow will be similarly restricted as the requirements for consistent water quality are of prime importance to avoid damage to the membranes.

Desalination processes are environmentally unfriendly, insofar as they rely on large amounts of energy for operation and produce a waste flow more saline than the original raw water.

The requirements of land take, constant water quality, consistent water levels, low pollution risk, and power requirements, dictate that desalination plants to serve the Thames region would have to be based away from the Thames estuary, on either the Essex or South coasts. Abstraction of seawater and discharge of reject brine would be likely to encounter significant environmental problems on the ecologically sensitive Essex Coast.

Desalination plants produce a very low dissolved solids water, which must be brought up to acceptable potable standards by part mixing with the parent water and chemical dosing, or blending with significant quantities of water of a suitable quality. Since these volumes are unlikely to be available at the Essex or South coasts, production costs, already very high, will rise with chemical dosing. The alternative of piping aggressive desalinated water to blend with water in the Thames region is likely to be significantly more expensive.

Given the high costs of production, likely high costs of transmission to sites within the Thames region, the high operating costs, and the environmental difficulties outlined earlier, it is considered that desalination should not be considered as a viable resource option in the foreseeable future.

5.0 DEVELOPMENT OPTIONS WITHIN THAMES REGION

5.1 General

Chapter 4 presented a broad review of the various water resources development options considered by the study. In this chapter the promising options within the Thames Region are reviewed in more detail in terms of general outline, engineering outline, resource value, water quality, environmental impact and costs.

Resource values have been derived from operation of the NRA Water Resources Model described in Appendix 6. Details of source operations are based on model output from runs where development scenarios, consisting of combinations of options were tested at demand levels up to 2021.

5.2 Thames-Side Groundwater

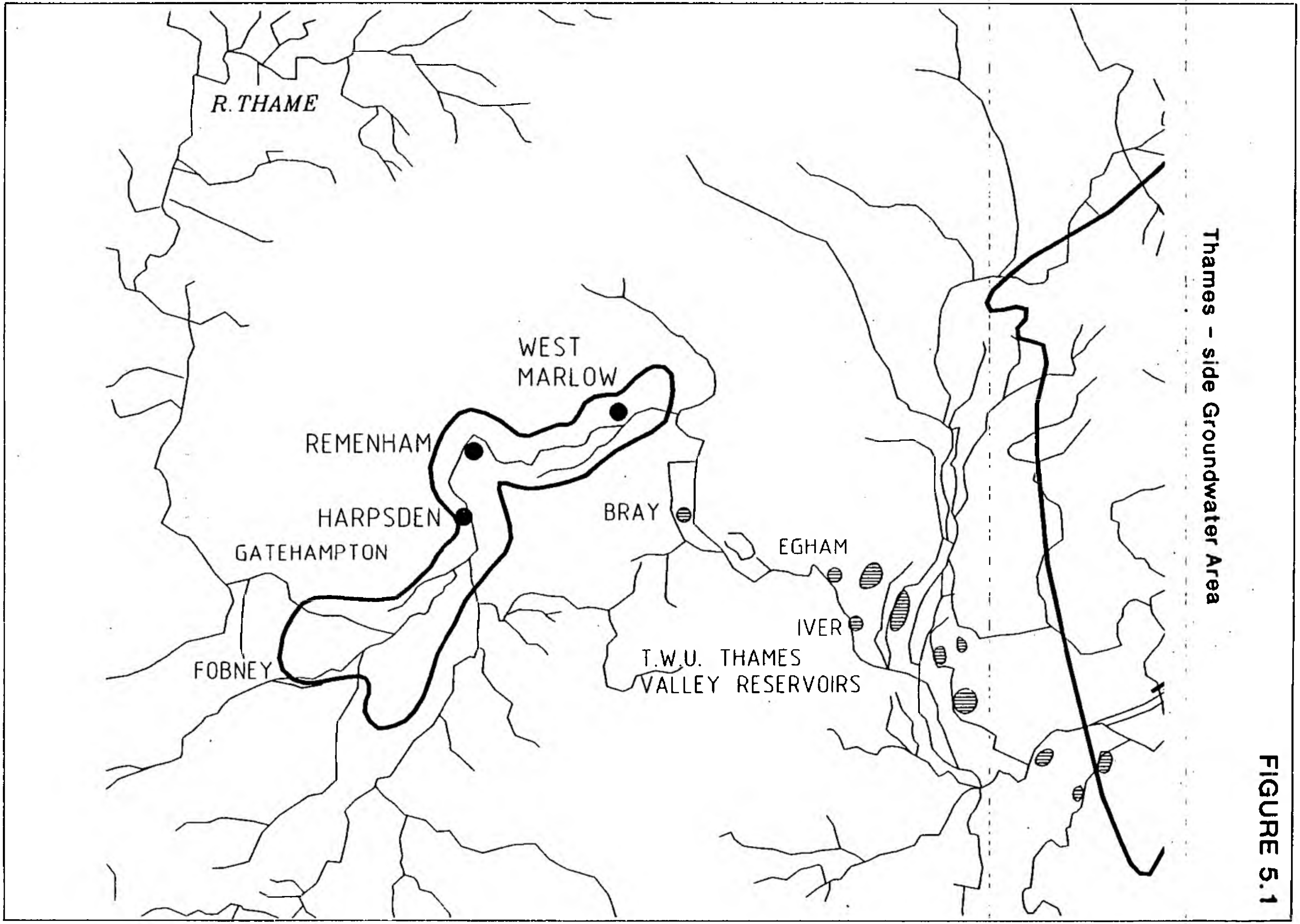
5.2.1 General Outline

Groundwater development in the Chalk aquifer adjacent to the River Thames in the Reading to Marlow reach is considered feasible, up to a total of 70 Ml/d. Figure 5.1 shows the area under consideration by Thames Water Utilities.

5.2.2 Engineering Outline

Works required at these groundwater development sites will involve:-

- construction of abstraction and monitoring wells
- headworks to wells
- pumping stations and distribution pipelines
- disinfection plant probably using chlorination.



Thames - side Groundwater Area

FIGURE 5.1

Water will be used for supply within the upper Thames catchment, with effluent return to the river.

5.2.3 Resource Value

The possible yields from the sites are:-

Site	Possible Yield Ml/d	Comment
Reading Area	30	Investigation underway
Harpesden	15	Already licensed
Remenham	15	Derogation possible
West Marlow	10	Pump tested
Speen or East Woodhay	5	Link to Bishops Green source

It is assumed that these yields will be available on a continuous basis, and the total resource value is assumed as 70 Ml/d.

5.2.4 Water Quality

The abstracted water will be of good potable quality probably only requiring disinfection before being put into supply. We have assumed that nitrate levels will be below EC limits.

5.2.5 Environment

Effects on the environment are expected to be minimal following construction. Permanent buildings and works will be unobtrusive.

There is some potential for derogation of groundwater levels in surrounding areas, particularly at Remenham but this can be controlled by the licence conditions.

The sources could influence local base flows discharging to the Thames, but the return of the water as effluent in the upper catchment will offset this impact.

5.2.6 Cost

Costs have not been derived for this option as investigation and testing works are well advanced and implementation is complete or imminent. All of the schemes are expected to be in use by 1996.

5.3 London Basin Groundwater

5.3.1 General Outline

In this option it is envisaged that the confined Chalk/Basal Sands aquifer of the London Basin (see Figure 5.2) will be operated by Thames Water Utilities under a single management regime incorporating the following components:-

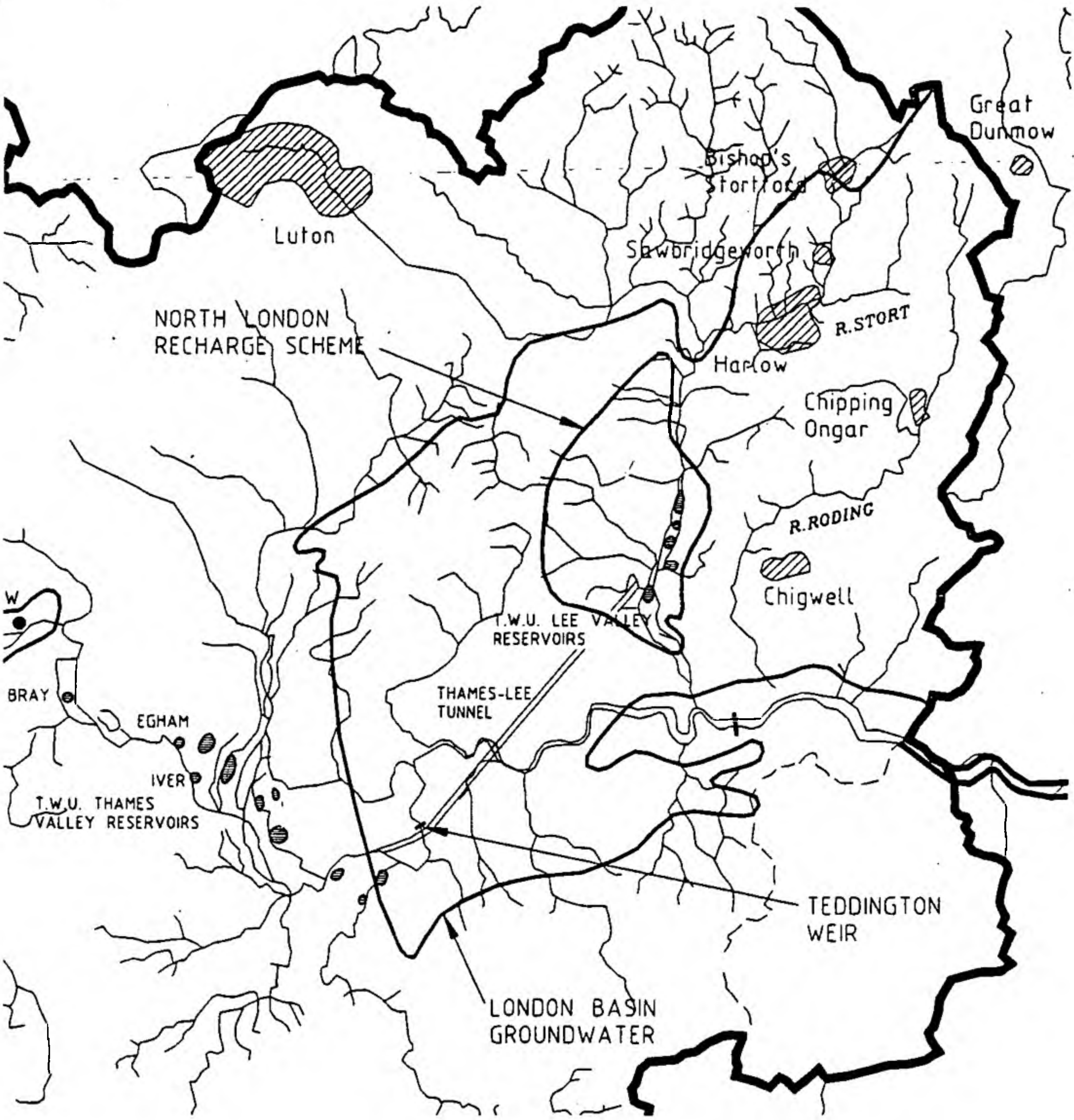
- North London Artificial Scheme
- South London Conjunctive Use Scheme
- existing licensed groundwater abstraction with increased uptake
- additional licensed abstraction to control rising groundwater levels.

The optimum development strategy for this resource comprises a base load abstraction to maintain groundwater levels at a level below that at which damage would occur to buildings and services in central London, and a peak load abstraction that uses the significant storage in the aquifer system during drought periods (1 in 7 to 1 in 10 dry years).

Previously developments of the resource have been considered in isolation. However, simulation modelling of this groundwater resource by the NRA has quantified the base load and peak load potential. Existing and proposed developments have been included in the overall option.

FIGURE 5.2

London Basin Groundwater Area



The North London Recharge Scheme of TWUL comprises dual-purpose recharge/abstraction boreholes and wells in the Lee Valley and the Enfield-Haringey areas (see Figure 5.3). Abstracted water is discharged to the adjacent reservoirs in the Lee Valley or the River Lee, and to the New River respectively. The schemes are based on low pressure injection of off-peak mains water into storage in the unsaturated Chalk/Basal Sands aquifer, and subsequent use of the storage as required.

In South London, TWUL have modified the proposed South London Recharge Scheme into a conjunctive use scheme in which groundwater abstraction will be decreased with preferential use of the London Ring Main during normal situations, but in dry periods the groundwater abstraction will be significantly increased, drawing on the storage built up in the aquifer. Abstracted water will be discharged into the Ring Main.

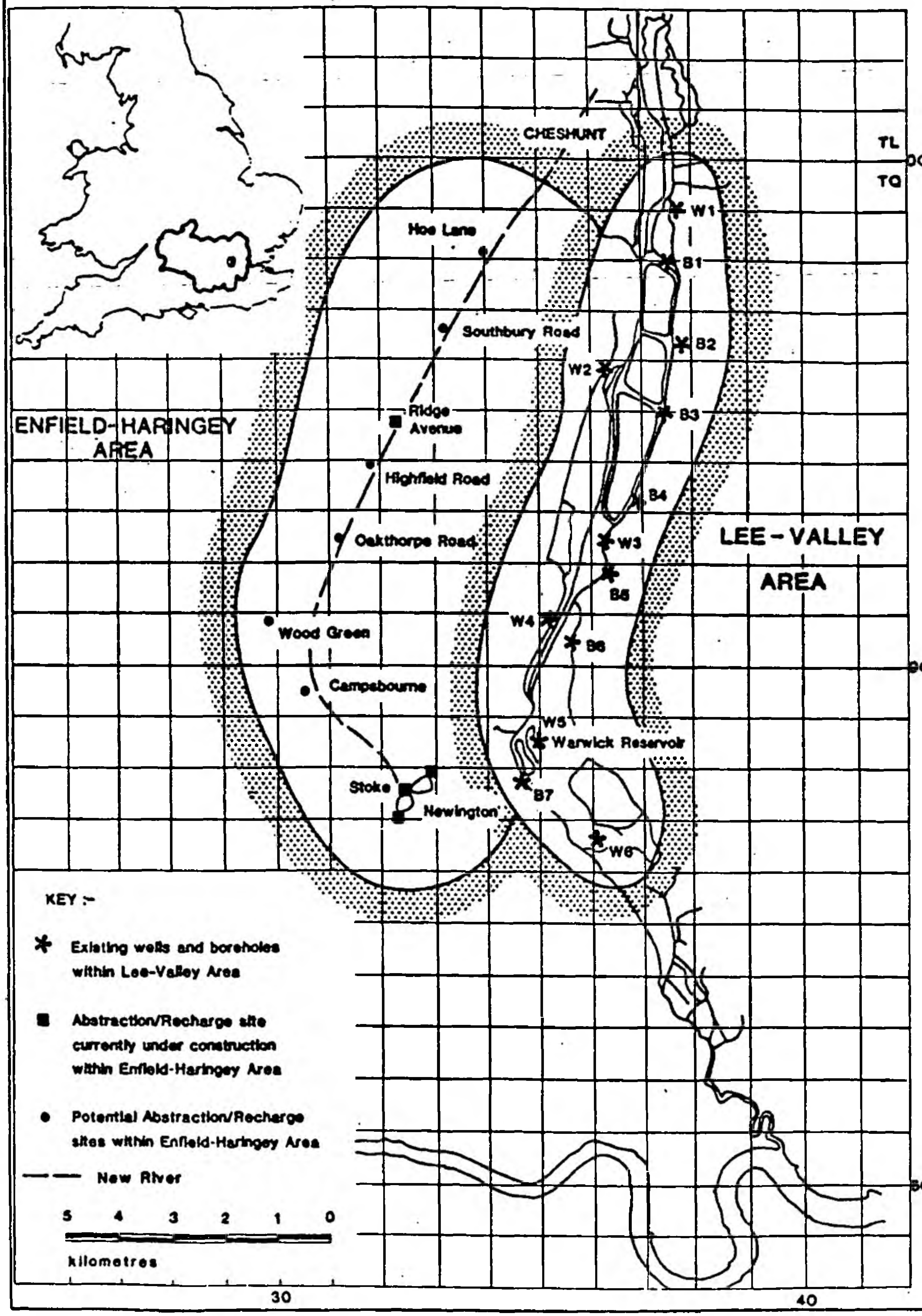
The present abstraction from the confined London Basin aquifer is around 121 Ml/d of which 23% is for direct non-public supply use, with the rest taken for public supply. Direct users only take about 50% of their licence entitlement. It is considered that licence adjustments could lead to a 30 Ml/d uptake by existing licensees.

Rising groundwater levels in the London area have been the subject of considerable concern for the last decade. Potential adverse effects are seepage into basements and tunnels; damage and instability to buildings, and chemical attack on buried steel and concrete. Modelling has shown that a further 30 Ml/d abstraction will stabilise groundwater levels at the interface between the Basal Sands and the London Clay, or at 1985 levels where these are above the interface.

Abstraction boreholes can be located so as to produce potable water for public supply while controlling groundwater levels, and minimising connection to the distribution system or the Ring Main.

Figure 5.3

North London Artificial Rechare Scheme



All of these components can be combined into an overall aquifer management strategy, involving conjunctive use. Operation of the aquifer will need to be linked to use of the lower Thames reservoirs, especially for the drought periods, and an overall review of groundwater licence for the London Basin will be required.

5.3.2 Engineering Outline

The proposed groundwater management scheme will involve the following works:-

- completion of the North London recharge scheme by construction of 14 new boreholes at sites adjacent to the New River (see Figure 5.3), and linkage to the distribution system;
- construction of 20 new boreholes in South London and linkage into the distribution system;
- construction of boreholes at 15 sites (2 Ml/d yields) in London to control rising groundwater levels and linkage to the distribution system;
- possible replacement or refurbishment of existing boreholes, and pump replacement.

Careful selection of abstraction sites will ensure that the water can be put into supply while groundwater levels are stabilized at or below those at which buildings and services will be affected.

Operation of the groundwater management scheme will involve the following measures:-

- encouraging an additional 30 Ml/d uptake by existing licensees above the present base load abstraction of 121 Ml/d
- an additional 30 Ml/d abstraction to control groundwater levels;

- trickle recharge in North London (Enfield-Haringey and Lee Valley) from the mains distribution system during normal years, depending on storage levels in the aquifer;
- abstraction from all of the boreholes in dry years (say 1 in 7 to 1 in 10 years).

5.3.3 Resource Value

The increase in the base yield over the present value of 121 Ml/d will be 60 Ml/d, of which 30 Ml/d will be from increase in uptake by existing licencees and 30 Ml/d for control of groundwater levels. Assuming the boreholes are operated on a continuous basis, the base yield and estimated resource value is therefore 181 Ml/d.

Peak yields, based on the modelling simulations run on the Water Resources Model, will be an additional 170 Ml/d from operation of the North and South London Schemes. At 2021 demands, the North London is used in 12 years out of the 70 year record, at a rate of 173 Ml/d for an average of 95 days over the 12 years, to give a resource value of 93 Ml/d. Operation of the South London Conjunctive Use Scheme is required in 13 years in the 70 year period, for an average of 102 days over the 13 years. Abstraction rates average 107 Ml/d, with a maximum of 125 Ml/d, to give an estimated resource value of 78 Ml/d. For both schemes the resource value is based on operation for up to six months of the years they are used.

Overall, the estimated resource value of the London Basin groundwater is 350 Ml/d, considerably greater than the presently used resource value of 121 Ml/d.

5.3.4 Water Quality

A key factor in the proposed aquifer management regime will be the extent to which abstracted water quality is affected by leaching out of oxidised gypsum and pyrite products from the Basal Sands following desaturation - resaturation cycles. High sulphate, calcium, magnesium and iron values could result. This requires further investigation, perhaps based on the North London Recharge Scheme.

5.3.5 Environment

Apart from limited impact during the construction phase, which can be mitigated by design and construction measures, the adverse effects on the environment are likely to be limited.

Operation of the scheme will have little or no impact on conditions in the unconfined aquifer of the Chilterns and the North Downs, and will not therefore effect river flows.

Implementation of the aquifer management programme will need to take account of possible derogation of private wells and boreholes, with mitigation measures such as lowering or replacement of pumps, or provision of a compensation piped supply.

By controlling groundwater levels in Central London the option will prevent potential damage and remedial measures to buildings and tunnels which were constructed at the times of low water levels, and reduce the construction measures otherwise required for new buildings and tunnels. The potential savings were estimated by CIRIA at tens of millions of pounds, perhaps over £150M.

5.3.6 Costs

Roughly half of the Enfield-Haringey artificial recharge scheme is complete and licensed, while the adjacent Lee Valley recharge scheme is fully licensed and operational. Works are also underway on the South London boreholes.

In view of the advanced nature of this option, and its imminent implementation, say by 1996, costs have not been established.

5.4 Reservoir at Abingdon/Drayton

5.4.1 General Outline

The potential reservoir site identified by TWUL after prolonged and extensive studies on a regional basis is located in the Abingdon area, just to the west of Drayton (see Figure 5.4). The selection by TWUL was based on engineering, environmental and cost grounds, after looking at over 50 sites.

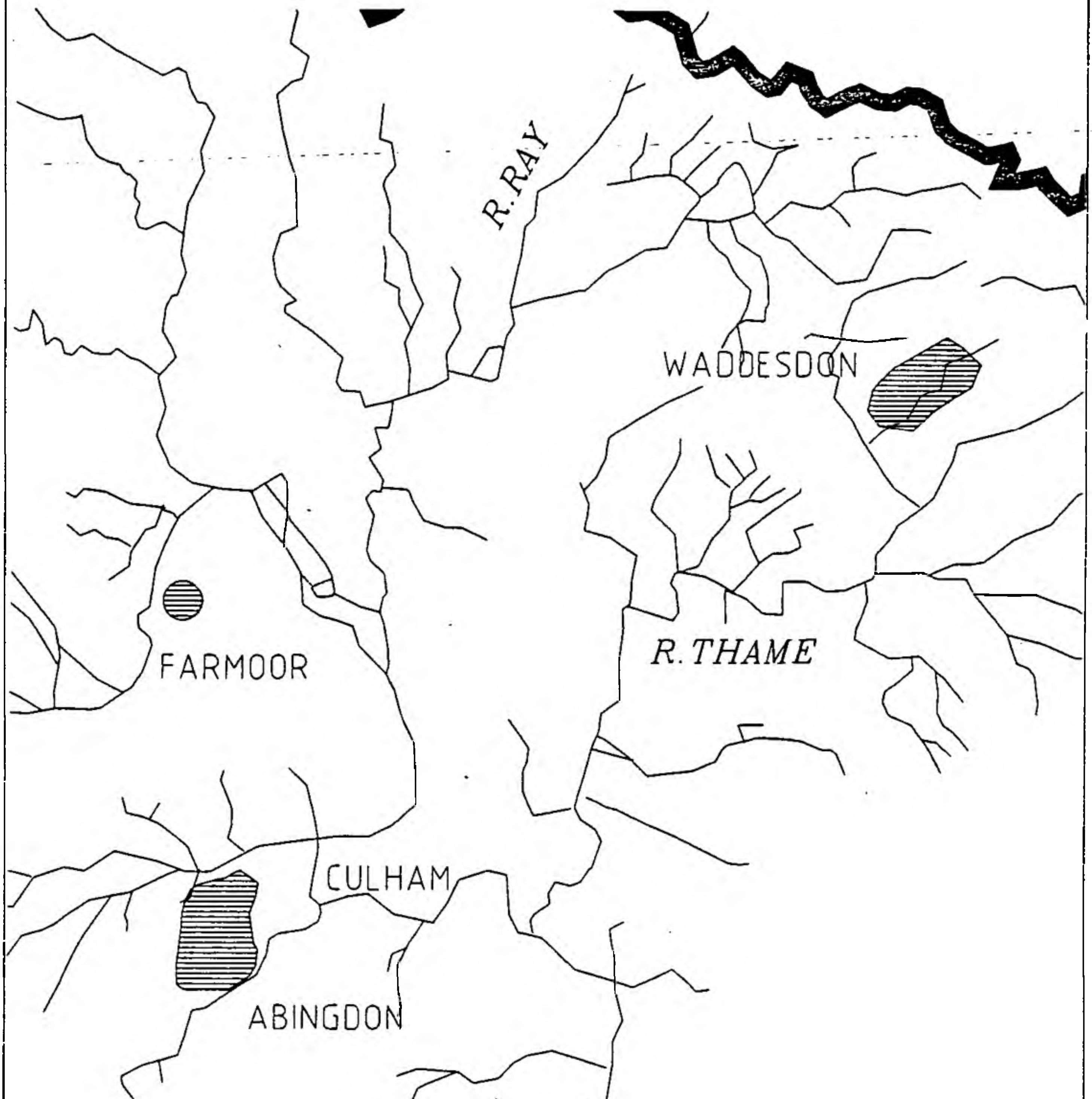
At present detailed site investigation, engineering and environmental studies are in progress. The outcome of these studies will influence the character and nature of the proposed scheme which is not known in any detail at present.

It is possible that the development may comprise two reservoirs, north and south of the railway, possibly, linked. However, this would be likely to be more expensive than a single reservoir north of the railway. Adoption of a single reservoir will depend on the geotechnical suitability of the northern area, that is, whether the Oxford clay extends over a sufficiently large area to provide the storage required.

The storage of the proposed reservoir has not yet been established. Figures ranging from 75,000 Ml to 140,000 Ml have been discussed. For the purposes of this study storage of 100,000 Ml has been assumed.

FIGURE 5.4

Reservoir at Abingdon/Drayton



Water will be drawn into the reservoir from the river Thames in the Culham reach, upstream of the Abingdon STW discharge. Direct supplies will be taken from the reservoir for treatment and transmission to the upper Thames area via the Farmoor-Cotswolds link. Releases will be made from the reservoir to the Thames for abstraction to the lower Thames reservoirs.

5.4.2 Engineering Outline

Based on the assumption of a single reservoir, north of the railway line, with a storage of 100,000 Ml, a possible layout has been adopted for the purposes of this study (see Figure 5.4). The reservoir will be completely bunded, with a maximum bund height of around 20m.

The intake will be on the Culham reach of the Thames, above the discharge from Abingdon STW. Transmission to the reservoir will be either by pipeline around Drayton, or more probably by tunnel on a more direct route. Alternatively, or perhaps in addition, there could be an intake just downstream of the Thame confluence to take advantage of the significant winter flows in the tributary. Discharge to the Thames from the reservoir will be via the sam aqueduct. A maximum abstraction rate of 600 Ml/d has been used in our resource and engineering studies. In practice permissible rates would be banded up to this maximum according to the difference between river flows and a prescribed flow set at Day's weir.

Preliminary modelling and consideration of the prescribed flow by the NRA has resulted in a figure of 450 Ml/d. This figure has been used for the purposes of this study, but is likely to be revised in the light of future more detailed studies.

Releases to the Thames from the reservoir to a maximum of 600 Ml/d would provide an increased yield to the lower Thames reservoirs of 200 Ml/d. At present notional release losses of 5 percent have been assumed in the transfer to the lower reservoir intakes, but this aspect needs to be looked at in the light of operational experience elsewhere.

The requirement for releases will depend upon the relationship of residual flows to the prescribed flows in the Thames at Teddington weir in and the storage situation in the lower Thames reservoirs.

Licensing of abstractions and discharges will require linkage with prescribed flows at Day's weir, Teddington weir, and all abstraction licences on the lower Thames.

The present Thames Water Utilities programme for this option appears geared to a public enquiry in early 1994, commencement of construction in 1996 and completion by 2001.

This option will comprise:-

- river intake/outlet in Culham reach with an additional or alternative inlet/outlet just downstream of the Thame confluence, with low lift pump station;
- transmission tunnel to reservoir (about 2.5m diameter);
- bunded reservoir, of unknown shape and size, but nominally with 20m high bunds and a storage of 100,000 Ml;
- reservoir off-take, pump station and water treatment plant to provide up to 100 Ml/d of potable water, with forwarding pumps and pipeline to take water to Swindon and the Cotswolds;
- possible reservoir oxygenation/bubbler system to turn over storage and prevent stratification/eutrophication.

5.4.3 Resource Value

Simulation of operation of the reservoir based on the control rules outlined above, using the Water Resources Model, has shown that it has a resource value of 200 Ml/d for the London area and 66.5 Ml/d for the Upper Thames.

Over the 70 year simulation period, 1920-1989, water was abstracted to the reservoir every year, for an average of 278 days, at a mean rate of 435Ml/d and a peak rate of 600Ml/d. Water was not available for abstraction for an average of 55 days per year. Augmentation to the Thames took place in 39 years out of the 70, with a mean rate of 468 Ml/d and a maximum rate of 600 Ml/d, for an average of 163 days over the 39 years.

5.4.4 Water Quality

Issues of water quality with this option are primarily related to the effects of storage in the reservoir, and the impact of any quality changes in the reservoir on discharges to the Thames.

The water taken into storage will be of a similar type and quality to that taken into the TWUL Farmoor and lower Thames reservoirs. It should meet the requirements of the appropriate EC Directives.

The Thames is a relatively nutrient-rich river and it is possible therefore that the reservoir water could become eutrophic, resulting in the outbreak of algae blooms. Some algae species, notably blue-green algae, produce toxins and become increasingly dominant as eutrophication proceeds. Some of the algae toxins can affect humans who swallow water whilst swimming.

Eutrophic water within the reservoir is unlikely to have a major impact on recreation and other uses. However, the effect of releasing algae rich water to the Thames could be significant, and controls will need to be placed on the discharges such that there is no impact on the river.

Depending upon the operation of the reservoir, there could be minor changes in the water chemistry due to:-

- eutrophication and algae blooms
- increased concentration of ammonia, iron and manganese due to oxygen depletion in summer or decay processes;
- concentration of Group 1 and 2 substances.

Again release of water of significantly different quality to the river could lead to adverse impacts on the lower Thames.

The changes in water quality can be minimised by operation of the reservoir, including:-

- artificial aeration to maintain oxygen levels
- artificial destratification to maintain the reservoir in an isothermal condition
- artificial circulation
- multiple draw-off levels

5.4.5 Environment

a) Construction

Land take will be extensive but this is tempered by the fact that the land in question is a mixture of Grades 3 and 4, moderate and poor, of the Agricultural Land Classification. In the light of a trend toward a more general protection of the better grades of land it is felt that the issue of agricultural land-take will not be as significant as it would have been 5 - 10 years ago.

The impacts arising from construction of the scheme will be considerable. Although not involving the loss of a significant number of dwellings within the reservoir area, the site will be in comparatively close proximity to Steventon and Drayton, with consequential potential for disturbance through noise, dust, vibration and traffic movements. River works may involve limited disruption of navigation and amenity.

There will be a major impact on landscape and visual effects, however no designated landscapes are involved and therefore impacts are likely to be assessed largely for their visual impact on residents and other receptors. With appropriate landscape works to the reservoir itself, and to the associated infrastructure, it should be possible to mitigate most detrimental visual impacts, despite the scale of the development. There will be an inevitable effect on the local landscape, but this in itself will not necessarily constitute a negative impact.

There is little evidence of archaeological interest on the site but it is highly likely that a site of this size will yield features of archaeological interest and a comprehensive desk study and a field survey will be required.

The proposed area is under intensive agricultural production and therefore is of limited value in nature conservation terms. There are no designated conservation sites in the area, however possible impact on the Barrow Farm Fen SSSI located 2 - 3 km upstream of the site on the Sandford Brook will need to be considered.

b) Operation

Creation of sailing, canoeing, bird watching and other water based recreation will be a very positive impact arising from the development. The details of what activities will be permissible are not yet available, but the reservoir will form a major recreational resource, probably of regional significance.

With careful design and management the reservoir can be of considerable benefit to wildlife. A number of existing reservoirs in the UK have been designated SSS's, usually for their wildfowl interest. The Abingdon reservoir has the potential of becoming an important wetland area in the south east of Britain.

Implementation of the reservoir and provision of a supply of up to 100Ml/d for the Upper Thames strategy area would allow reduction in groundwater abstraction in the Cotswold region, thereby alleviating low flow conditions in a number of chalk streams and rivers.

The operation of the reservoir will modify the river regime acting to reduce high winter flows and increase flows in summer. Resulting flow changes are shown in Appendix 2 for Day's Weir. There would appear to be little effect on high flows, although some benefit will arise from reduction in flooding risk downstream. Significant increases in low flows will result from the scheme, particularly in drier years.

The NRA River Control and Navigation Department have indicated that they do not envisage any significant problems arising from the operation of the scheme.

Reduction in winter flooding may, depending on the extent of the reduction, have significant adverse impact, on downstream sites of nature conservation interest where value relies on periodic winter flooding or water levels in general. There are numerous wetland sites located downstream of Abingdon although they are largely of county rather than national importance comprising Clifton Hampden Meadows, south Stoke Marsh, Cholsey Marsh (a BBONT Nature Reserve), Shilling Pond Meadows and Hayward Eyot. A nationally important site, Culham Brake, is located directly upstream of Culham Reach. A Berkshire, Buckinghamshire and Oxfordshire National Trust (BBONT) survey in 1984 estimated there are at least 53, wetland, carr or open water sites on the middle and lower Thames which are periodically inundated.

A full study of sites of ecological value and consultation with English Nature and the local National Trusts is required to determine whether these sites with a need for flooding will be affected.

The change in river regime could lead to alteration of sedimentation on the downstream meadow, reducing flushing by winter floods and increasing sediment loads in summer. This requires further investigation.

It is likely that the scheme may impact on ecology and fisheries due to changes in the downstream water quality, flow and sedimentation regime, and detailed consideration will need to be given to these aspects to determine whether these impacts will be significant and what mitigation measures, if any, are needed to ameliorate these impacts.

Invertebrates are adapted to their environment and any alterations in temperature (release of warmer reservoir water in summer), flow, substrate, vegetation, food supply and water quality will alter the composition and abundance of stream benthos. With so many interrelated factors it is difficult at this stage to predict the likely impacts that may result, however adverse impacts on the macroinvertebrate community are more likely to occur through indirect effects of changes in the sedimentation regime than in the changes per se. Increased sedimentation is more likely to result in subtle changes in specific composition rather than gross changes.

Increased sedimentation may also adversely affect fisheries, particularly salmonids. Faunal changes again are likely to be subtle involving shifts in dominance of species and increases and decreases in overall abundance. In order to predict these changes with accuracy in relation to physical habitat, more basic work is needed on the factors controlling the distribution of individual agencies.

Set against these potentially adverse influences are the possible ecological benefits to be gained, not least of which is the general prescription of maintaining river flows above normal, and avoiding stress in the summer period.

5.4.6 Costs

For the purpose of this study we have taken the most recent cost estimates for the reservoir as provided by NRA. The estimated capital total cost is £330 million at 1991 prices. This figure excludes any cost for works necessary for water treatment or transfer to the Upper Thames area and operating costs are estimated at £0.5 million a year at full development.

5.5 Redevelopment of Staines Reservoirs

5.5.1 General Outline

This option is aimed at increasing the storage capacity of the TWUL lower Thames reservoir system. It involves deepening of the North and South Staines reservoirs by raising of the bunds and the removal of the separating bund thereby creating additional storage (see Figure 5.5 for location). Full feasibility studies are in progress. Firm details are not yet available and estimates of possible storage increases are in the range 7500 Ml to 15000 Ml. A value of 10000 Ml has been adopted for this study.

It is not possible to undertake these works until a suitably large additional resource becomes available to London so that the Staines reservoirs can be taken out of service. The works are expected to take 6 years to complete and modelling has shown the resultant temporary decrease in resource value in that period to be 91 Ml/d.

5.5.2 Engineering Outline

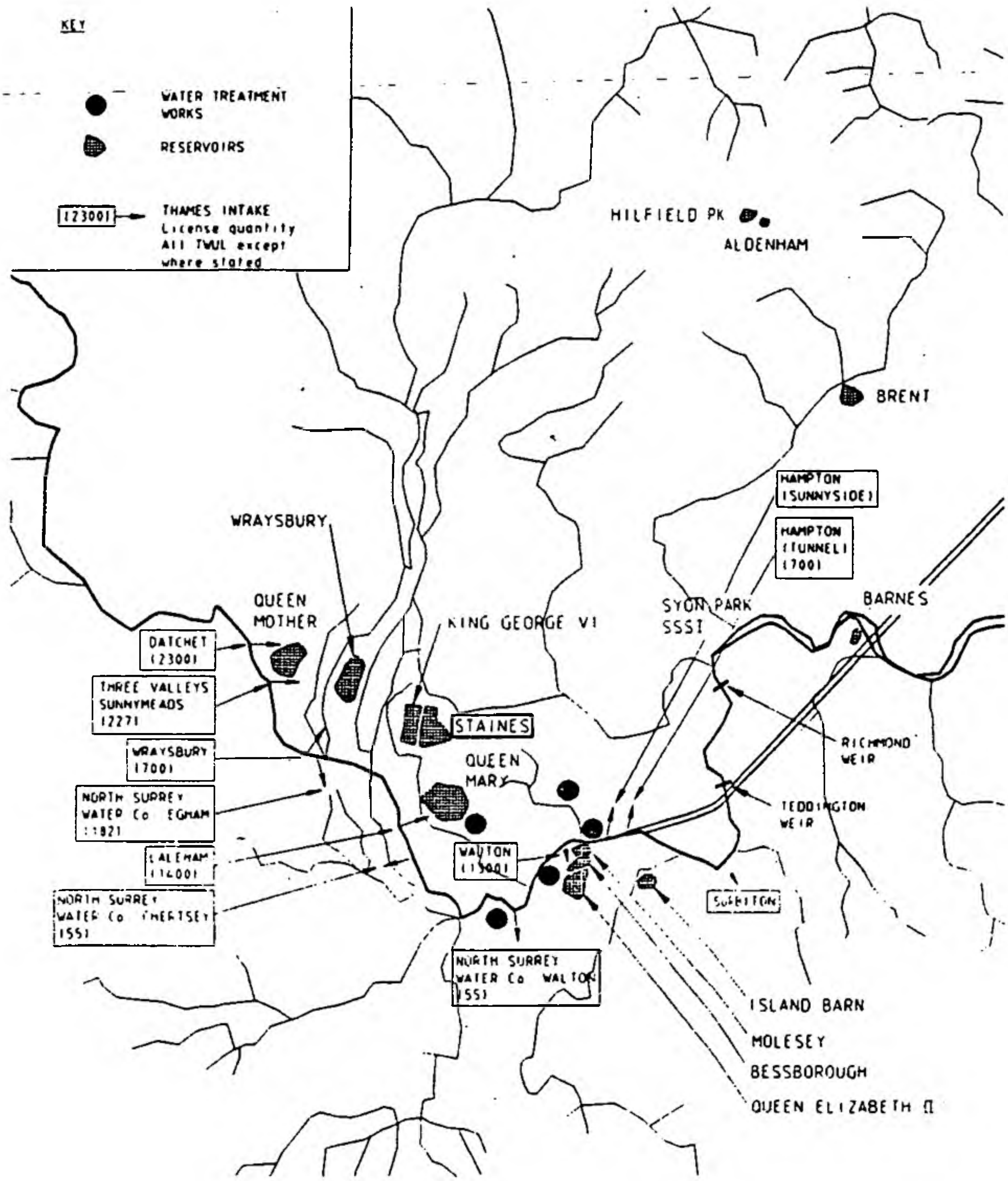
For the redevelopment of Staines reservoirs, the works would comprise the following in addition to necessary rehabilitation works to the existing bunds:-

- draindown of the reservoirs,
- increase in bund height,
- removal of bund separating two reservoirs,
- possible alteration to drawoff/fill arrangements,
- possible forced aeration/circulation systems,
- possibly additional pumping capacity.

The reservoirs are sited in built-up residential areas. Design and construction will need to take account of the safety aspects of the location, particularly with regard to the engineering of the heightened bunds.

FIGURE 5.5

RE-DEVELOPMENT OF STAINES RESERVOIR



5.5.3 Resource Value

Simulation in the Water Resources Model has indicated that the resource value of the additional 10000 Ml storage resulting from the works is 70 Ml/d. This figure and the existing value of 91 Ml/d, are based on operation of the reservoir for 100 days without replenishment. If the operating period is longer the yields will decline proportionally.

5.5.4 Water Quality

Under this scheme there are no aspects of water quality to be noted other than that redevelopment to form a larger, deeper, single reservoir may require the introduction of additional operational measures to prevent stratification and eutrophication.

5.5.5 Environment

a) Construction

There will be considerable impact arising from construction of the scheme, with potential for disturbance through noise, dust, vibration and traffic movements.

Impact on the landscape of the heightened bunds may also be considerable, for residents and other receptors. It is not clear to what extent land constraints will allow mitigation of the impact by landscape works on the bunds and surrounds.

b) Operation

Once back in operation no sigificant change from present conditions is foreseen.

5.5.6 Costs

The capital cost of the works required to increase the capacity of Staines reservoirs is estimated to be £20 million and the additional annual operating costs about £0.1 million.

5.6 Re-use of Effluents Discharged to the Tidal Thames

5.6.1 General Outline

Over 2400 Ml/d of treated effluent is presently discharged to the tidal reaches of the river Thames. This option involves re-use of effluent from the Mogden and Deephams STW's which are conveniently placed with respect to the water supply reservoirs and treatment plants on the lower Thames and the river Lee respectively (see Figure 5.6). Consented dry weather flows at Mogden are 420 Ml/d, and 200 Ml/d at Deephams.

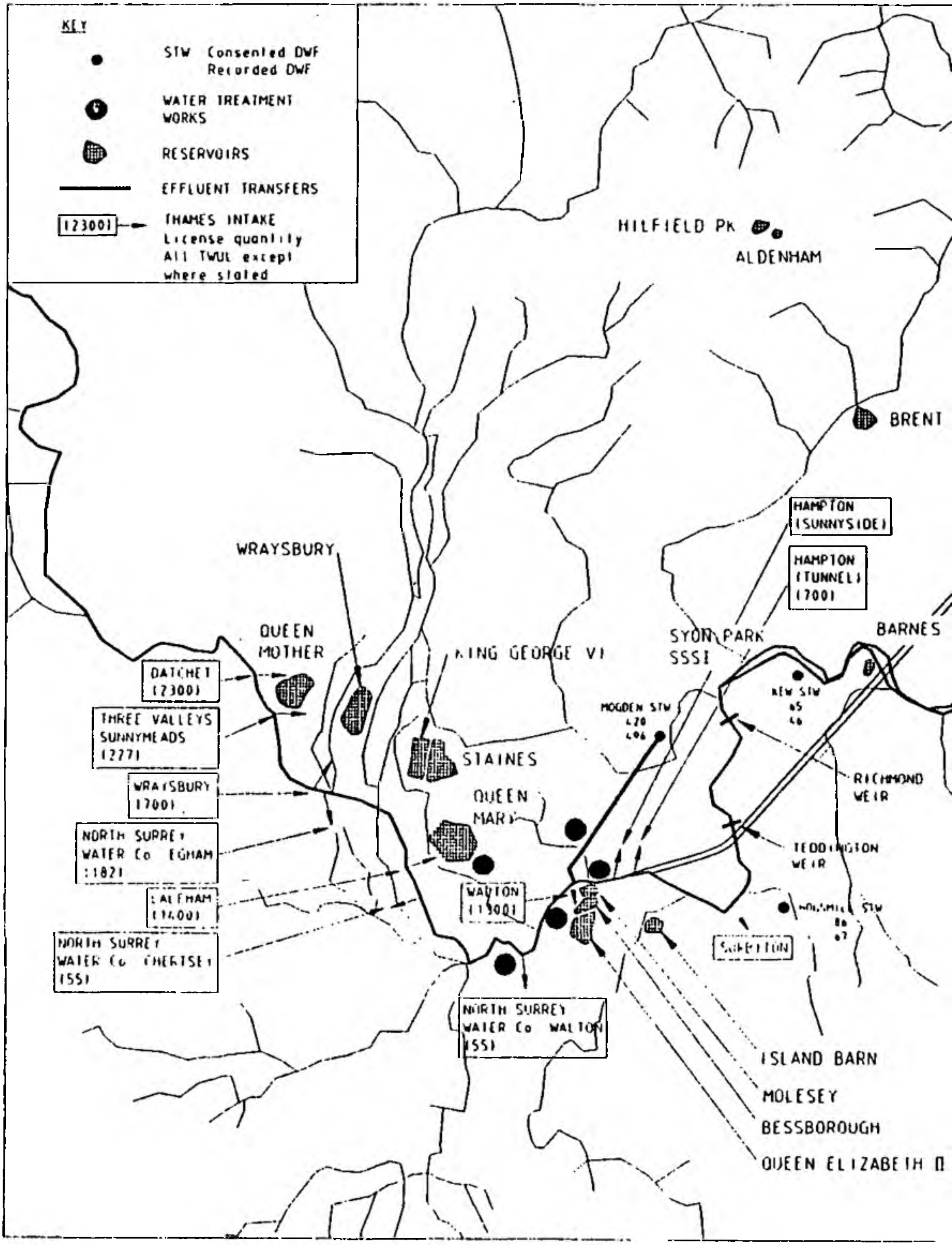
The major effluent discharges to the tidal Thames at Beckton and Crossness STW's, with present dry weather flows of 1030 Ml/d and 604 Ml/d, occur downstream of the Thames Barrier and are therefore comparatively more difficult and costly to develop.

Present effluent quality will be improved by tertiary treatment which will comprise filtration followed by ozonation to reduce suspended solids and BOD respectively.

Re-use of the treated effluent could include:-

a) discharge to the river Thames above Teddington weir but below the main abstractions, thereby allowing additional abstractions,

b) mixing with raw river water at or in storage reservoirs in the lower Thames and the Lee Valley,


KEY
STW Consented DWF
Recorded DWF
WATER TREATMENT WORKS
RESERVOIRS
EFFLUENT TRANSFERS
(2300)
THAMES INTAKE
License quantity
All TWUL except where stated
HILFIELD PK
ALDENHAM
BRENT
HAMPTON (SUNNYSIDE)
HAMPTON (TUNNEL) (700)
BARNES
WRAYSBURY
QUEEN MOTHER
KING GEORGE VI
SYON PARK SSSI
DATCHET (2300)
THREE VALLEYS SUNNYMEADS (277)
MOGDEN STW 420 406
KEW STW 65 46
STAINES
RICHMOND WEIR
WRAYSBURY (700)
QUEEN MARY
NORTH SURREY WATER Co EGHAM (182)
TEDDINGTON WEIR
WALTON (1300)
(1400)
STW 86 67
SURBITON
NORTH SURREY WATER Co CHERTSEY (55)
NORTH SURREY WATER Co WALTON (55)
ISLAND BARN
MOLESEY
BESSBOROUGH
QUEEN ELIZABETH II

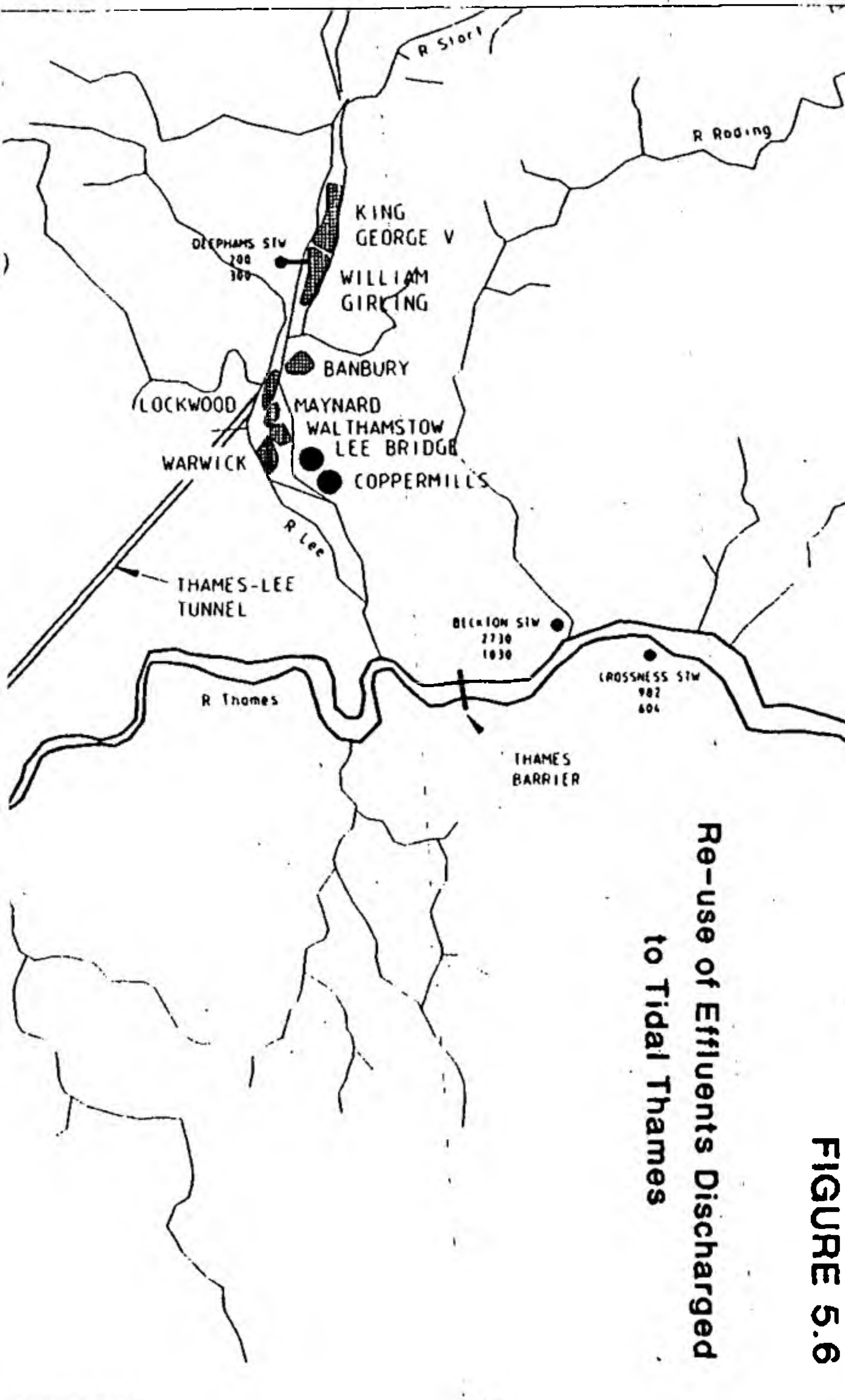


FIGURE 5.6

Re-use of Effluents Discharged to Tidal Thames

c) supply to the intakes of potable water treatment plant and blending with raw water prior to treatment,

d) direct introduction into the London raw water ring mains.

These sub-options are listed in descending order of likely public acceptability in promotion and implementation.

For the Mogden STW, it is envisaged that the tertiary treated effluent will be transmitted via a 2.0m diameter tunnel to discharge to the Thames in the Sunbury area, just below the Walton intake to the Queen Elizabeth II reservoir. This will allow additional abstraction at this intake and those immediately upstream. It will also allow increased transfers to the Lee Valley reservoirs via the Thames-Lee Tunnel.

Operation of the scheme would be triggered by flows at Teddington weir, and storage levels in the lower Thames reservoirs and any upstream regulatory reservoir such as that proposed at Abingdon/Drayton.

At Deephams STW there is no potential for a parallel scheme because of the flow regime of the river Lee. Instead it is anticipated that the treated effluent will be conducted by pipeline to discharge directly into the William Girling raw water storage reservoir.

Experience of effluent re-use world wide has suggested that a recycled content in the water supply should not exceed 25 percent or so. Accordingly, we have considered that only up to 50 Ml/d of the 200 Ml/d flow at Deephams should be developed, subject to operational experience.

Use of the scheme would be triggered by storage levels in the London reservoir and the London Basin aquifer.

5.6.2 Engineering Outline

The Mogden effluent re-use scheme will comprise:

- filtration plant,
- ozonation plant,
- pumping stations to circulate effluent through the tertiary treatment, and to transfer treated effluent to the river,
- 2.0m diameter tunnel, about 7.0km long, from Mogden STW to the river Thames at Sunbury,
- discharge works to the river, incorporating aeration.

At Deephams STW, the scheme will consist of:

- filtration and ozonation plant,
- 700mm diameter pipeline from the STW to William Girling reservoir,
- discharge works to the reservoir, incorporating aeration,
- pumping stations to circulate effluent through tertiary treatment and transfer treated effluent to the reservoir.

5.6.3 Resource Value

It would be possible to develop the effluent re-use scheme as outlined above to a maximum yield of 450 Ml/d. However, due to the likely difficulties of overcoming public perception of the aesthetics and risks of re-use of effluent we have considered that this option would only be implemented in the long term. Accordingly it has been introduced towards the end of the planning period in the modelling scenarios, and the full resource potential has not been determined.

The Deephams component has a resource value of 50 Ml/d. Modelling has shown it to be brought into operation in 37 years out of the 70 year period, for an average of 76 days in those years, although the maximum period was 359 days.

Potential at Mogden far outweighs that at Deephams. Discharge of Mogden effluent as proposed, above the intake for the Thames-Lee tunnel (70-90 Ml/d capacity), will allow additional water to be taken to the Lee Valley reservoirs. It would therefore appear preferable to develop the scheme based on Mogden only, so that it could be expanded as and when required. In the modelling to date, the maximum call on this option has been at 90 Ml/d, with operation in 31 years out of 70 years, giving a resource value of 68 Ml/d. The number of days of use over the 31 years averaged 85 days, with a maximum of 358 days.

5.6.4 Water Quality

The effluent quality after tertiary treatment has been assumed to be significantly better than normal consented discharges to the freshwater reaches of the Thames. Nutrient levels would be lower and dissolved oxygen content higher.

During recent dry years much of the summer low flows over Teddington weir has consisted of effluent discharge of normal quality from the Hogsmill STW. The effluent re-use scheme should therefore improve water quality during these events.

5.6.5 Environment

a) Construction

Impacts during the construction phase will be significant but can be mitigated. Construction of the tunnel will be a key activity. Exploration and design measures will need to be carefully considered to avoid adverse effects on buildings and structures.

Land take could be significant, but space may be available at the STW sites. Alternatively TWU sites for the treatment plant for the Mogden component may be available near the lower Thames reservoirs and treatment plants.

b) **Operation**

The introduction of effluent of a higher quality will improve river water quality in the lower reaches of the Thames above Teddington weir, as discussed above.

Preliminary use of the QUESTS estuary model by the NRA has indicated that removing present effluent discharges of the magnitude being considered here from the tideway would have a beneficial effect on tideway water quality, increasing dissolved oxygen saturation by up to 5%.

5.6.6 Costs

The capital cost of the Deephams scheme as outlined above is £14 million. Operating costs are assessed at about £0.4 million per annum at 1991 costs.

The capital cost of the Mogden scheme to return up to 90 Ml/d to the river is estimated to be about £30 million with annual operating costs of £0.6 million. The size of the tunnel would however allow transmission of effluent up to the full 400 Ml/d available, when required.

5.7 Other Storage Options Within Thames Region

5.7.1 General

As part of the option for transfers from the river Severn and from the Anglian region, limited storage has been included within the Thames region in order to provide for the June to August period when water is not likely to be available for transfer and to increase the potential benefit during the summer periods of maximum demand.

The size of storage reservoirs considered is considerably below that of the Abingdon/Drayton reservoir discussed in section 5.4. For the Severn transfer, use of 25,000 Ml storage in gravel workings in the upper Thames has been studied. In the case of the Anglian transfer via the river Thame, we have allowed for 30,000 Ml of available reservoir capacity at Waddesdon, near Aylesbury.

Engineering outlines and cost estimates for these reservoirs are presented in this section, together with water quality and environmental considerations. Resource values for the relevant transfer options are presented in Chapter 6.

5.7.2 Reservoir in Upper Thames Catchment

General Outline

From discussions with County Councils we have identified four potential storage reservoir sites within presently worked or proposed gravel working areas. These comprise (see Figure 5.7):-

a) Bampton

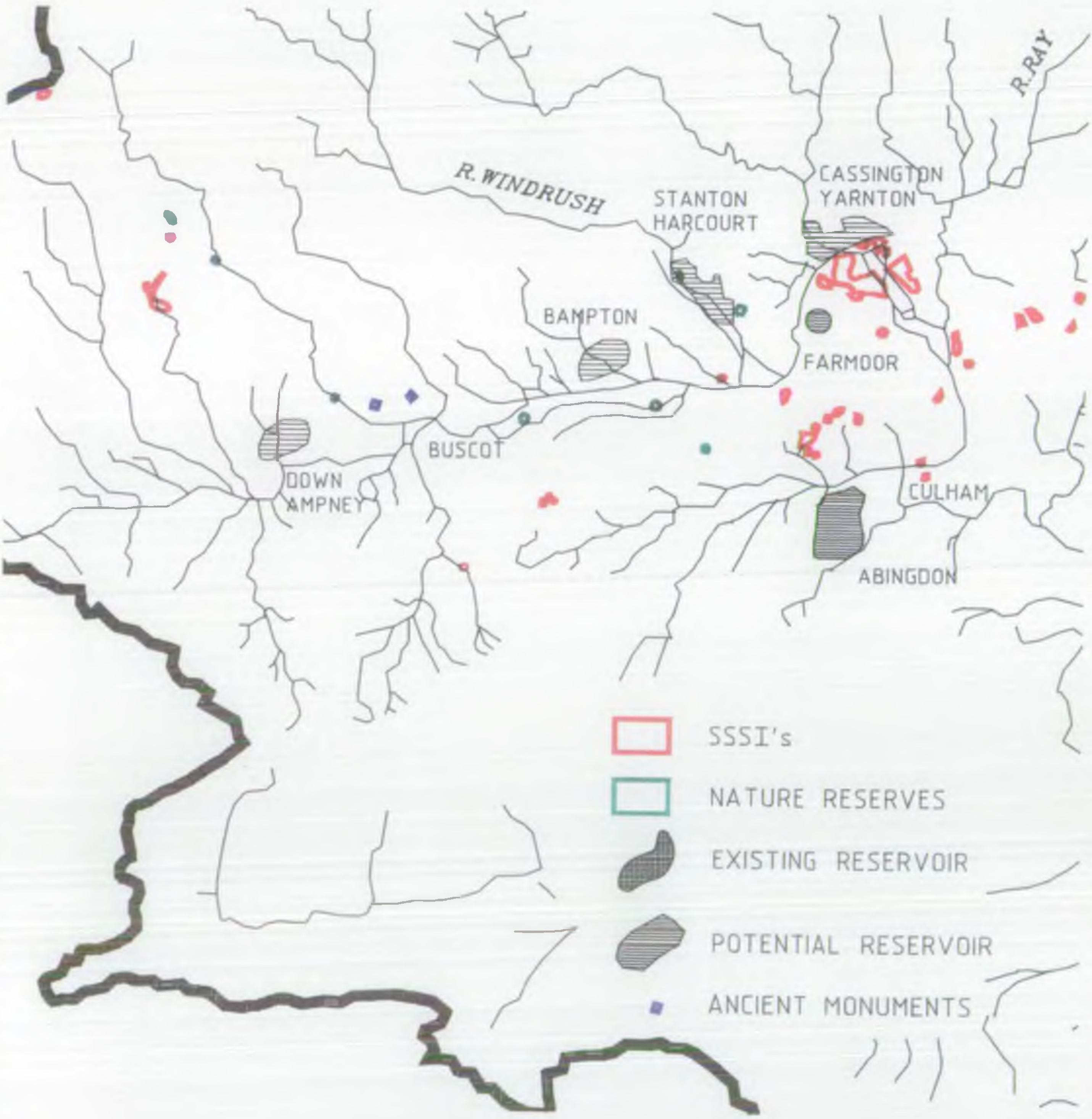
Development of gravel workings in the area between the river Thames and Bampton village is not in the present Minerals Plan of Oxfordshire County Council but is likely to occur within the planning horizon of our study. A reservoir at Bampton would be likely to impinge significantly on the flood plain of the river Thames, with consequences for flooding downstream. Since this area is not yet being actively considered for gravel extraction, we have not pursued it further.

b) Stanton Harcourt

New development is presently proposed around existing pits in the vicinity of Stanton Harcourt in the lower Windrush Valley. Planned final restoration is as lake areas, and a combination of the proposed and existing lakes could form a large linear storage in the lower reaches of the Windrush. At Stanton Harcourt the components of reservoir storage would severely impinge on the flood plain of the

FIGURE 5.7

Gravel Pit Storage in Upper Thames



Windrush and might require diversion or amendment of the Windrush channels.

c) Cassington-Yarnton

Gravel extraction began in 1990 and further areas are now subject to planning behest. Working will eventually extend to 600 ha. Final restoration policy is for open water, making this site attractive for consideration as a reservoir site.

The existing and proposed workings at Stanton Harcourt and Cassington-Yarnton (see Appendix 2) were examined but they do not appear to be able to readily provide the 25,000 Ml storage required under the proposed Severn transfer option if Abingdon/Drayton reservoir is not implemented.

d) Down Ampney

Development of land adjacent to the river Thames is likely to commence in the next 10 to 15 years and will cover some 7 - 8 km^2, offering the potential for significant storage of water. However, final restoration is at present to be as agricultural land because of the many nearby existing pits being utilised for the Cotswolds Water Park.

For the purpose of this study we have assumed a suitable reservoir storage could be formed at Down Ampney. Here gravel extraction could be planned with the eventual use of large scale water storage in mind. This site is also that most conveniently placed to receive transfers from the proposed Severn to Buscot pipeline. The gravel reserves could be progressively developed before and after implementation of the Severn transfer, to provide storage as required.

Engineering Outline

The works envisaged at Down Ampney to convert gravel workings to reservoir storage include:

- introduction of perimeter slurry trenches pit prevent seepage from or groundwater seepage into the gravel pits

- bunding around each pit to a height of 1m

- inter-connecting and by-pass pipework to each pit

- low lift pumping station for transfer to the river Thames at Buscot.

Appendix 2 shows the notional storage development used for the purposes of costing.

Water Quality

Transferred Severn water will be nutrient-rich and measures may be required to prevent eutrophication and oxygen depletion, such as forced aeration and circulation. The reservoir storage components will be shallow (5 - 6m) and temperatures may rise significantly above that of the river Thames in summer.

Environment

The issue of loss of agricultural land will normally have been addressed at the mineral extraction proposal stage. Therefore for those areas where the accepted restoration strategy is to water, the issue will not arise in connection with reservoir proposals.

Down Ampney is a notable exception to this scenario, as the Ministry of Agriculture Fisheries and Food (MAFF), and the planning authority strongly favour restoration to agriculture. A proposal for water storage will need to address this conflict, and it will be necessary to identify just how feasible restoration to agriculture would be..

Drainage may be a more critical factor, as the NRA-TR Drainage and River Management departments have raised the issue of loss of flood capacity as a potential constraint to the adoption of gravel pits for storage.

All of the gravel extraction areas identified lie at least partly within the flood plain of the Thames with the exception of Down Ampney which will affect flood areas associated with the Ampney Brook. While use of gravel pits for water storage as they exist at the end of working would raise no problems, if bunding above ground level were required then very significant areas of flood storage capacity may be lost. This could be an unacceptable impact on flood control and would be strongly resisted.

The issue of groundwater movement through gravels and interruption/diversion around sealed gravel pits is considered not to create significant environmental impacts.

In general terms, construction impacts will be less significant than for other reservoir developments as works will take place within existing void areas.

Restoration of water is often looked upon as a significant positive impact of mineral extraction. However, at Down Ampney, which already lies between two areas of water park, this would almost certainly be regarded as an undesirable impact. In all cases, the creation of large bodies of water within what is a predominantly agricultural landscape must be regarded as a significant landscape impact, although not always either detrimental or beneficial.

Low (1m) bunding above ground level may be required at Down Ampney. Therefore visual and landscape effects will be insignificant in comparison to the Abingdon proposal reviewed earlier. The same careful treatment of bunds through variation of line and slope will be required together with planning schemes in order to minimise the impacts of any purpose-engineered structures.

Impacts arising from infrastructure associated with gravel-pit storage will be similar to those discussed for Abingdon. Again, it will be necessary to minimise any impacts arising from the abstraction/discharge elements where they are proposed for riverside or other prominent locations.

Recreational benefits could accrue from use of gravel pits for water storage although planning policies are more likely to control uses than perhaps has been the case in the past, due to the extent of water based recreation already available in, for example, the Cotswold Water Park. The potential for such use will depend therefore to an extent on the location of the pit, and also on the fact that water levels in some years could fluctuate considerably. Negative effects on recreation or amenity aspects are considered unlikely to arise.

Due to the fact that this option utilises areas of worked out gravel pits, it is not considered that significant archaeological impacts will result.

The Down Ampney reservoir area does not have significant conservation constraints. There are no SSSI's or LNR's within the defined area, although there are a number of important wetland SSSI's just outside the area, Whetford Meadow and the North Meadow Cricklade Natural Nature Reserve (NNR).

Like the Abingdon reservoir, the Down Ampney gravel pits could provide nature conservation opportunities. Many gravel pits have been designated as SSSI's. There is however greater opportunity with gravel pit storage that abstractions will occasionally conflict with nature conservation. Careful design and management will help to eliminate this.

NRA Conservation department has expressed concern over any possible disruption to ground water flow. If the pits are sealed and do not draw in water from neighbouring streams no significant environmental impacts are foreseen.

The Upper Thames and its tributaries have just been proposed an 'Environmentally Sensitive Area' commencing in 1993. This would mean that farmers/landowners would be allocated grants to maintain or restore habitats of conservation interest, reducing intensive farming inputs.

This may mean that there would not be a presumption to allow the after use of gravel pits to be open water, rather, there would be encouragement to restore them to woodland and flood meadows. It is likely however that designation of an ESA will not make a significant difference to the policy context for this option.

Costs

It has been assumed that the only costs involved in providing gravel pit storage would be land acquisition, construction of the slurry trench cut-off, inlet and outlet structures, and access roads around the pits. It has also been assumed that any bunding necessary to maximise on potential storage volume would be covered by the winning of gravel. The estimated cost of providing a 25000 Ml of gravel pit storage at Down Ampney is £13 million.

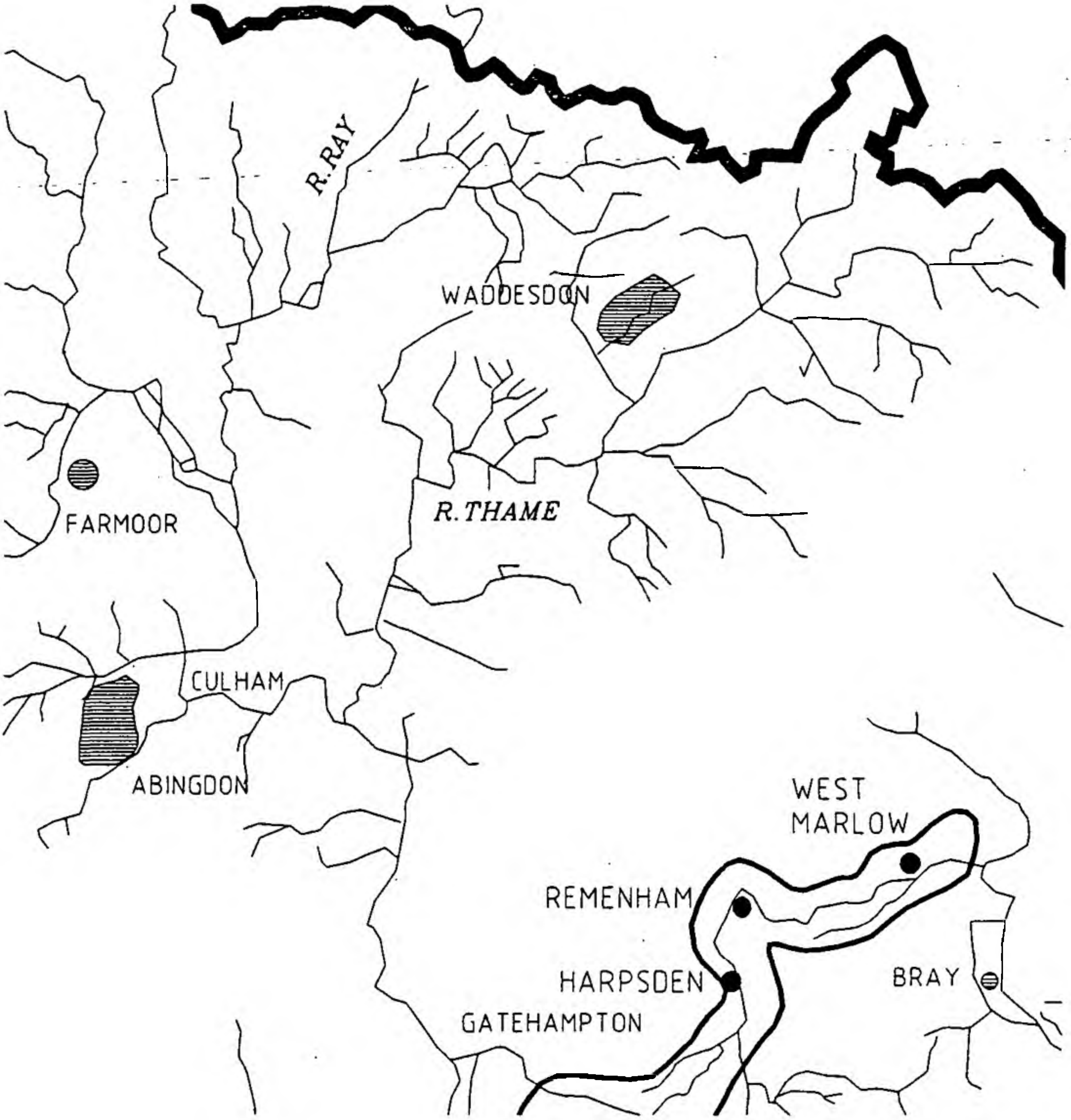
5.7.3 Reservoir at Waddesdon

General

The WRB investigated the potential for a reservoir in the valley below Waddesdon Manor in the 1960's with a capacity of up to 173000 Ml. In this study we have proposed a much smaller reservoir of 35,000 Ml total capacity as shown on Figure 5.8 and in Appendix 2. The reservoir site is underlain by Oxford clay.

FIGURE 5.8

Reservoir at Waddesdon



Engineering Outline

The reservoir would involve the following works:-

- 17 m high main embankment approximately 1200m long,

- 5m high saddle dam approximately 600m long.

Water Quality

Water transferred from Anglian region is likely to be nutrient-rich and with significant algal content. Water quality changes could occur within the reservoir as discussed for the Abingdon/Drayton reservoir, and the same mitigation measures of aeration and circulation may be required. The reservoir is likely to be shallow and extensive with significant warming to above river temperatures in summer, which will exacerbate any problems.

Environment

The proposed Waddesdon reservoir is within an Area of Attractive Landscaping identified by the Buckinghamshire Structure Plan. This policy is significant in relation to the reservoir proposed and if the option were pursued, early discussion with the planning authorities would be required in order to establish their attitude to the proposal in relation to the policy context.

Development impacts at the reservoir site would be considerable. The reservoir would result in the loss of up to 6 km^2 agricultural land, mostly of grades 3A and 3B. While significant, the loss is unlikely to be as contentious as when the proposal was last discussed with MAFF, however, objections made at that time are likely to remain, if perhaps with less force. It is important to note that up to 7 farmsteads could be inundated, involving significant compensation.

Local impacts on agricultural operations and drainage will arise from the pipeline, similar to those identified in other options. These will largely be temporary in nature, or can be satisfactorily mitigated through appropriate engineering solutions.

Very significant impacts will arise from the reservoir due to the structure proposed and the quality of the surrounding countryside. The reservoir proposed has substantially-less impact than that proposed in the 1960's which involved an embankment height of up to 41m which would have a major landscape and visual impact within the high quality countryside present.

Construction impacts associated with the reservoir are likely to be more significant than at Abingdon, primarily due to the topography and quality of the existing countryside, but also because access to the site is poorer - and more resistive to change.

A detailed analysis of the reservoir site and its surroundings should be undertaken to identify existing features and characteristics and to establish key views. This will then enable a comprehensive analysis of visual and landscape impacts, essential if this option it to be taken forward.

A number of footpaths would be either lost entirely or require major realignment around the periphery of the reservoir. Due to the attractive nature of the countryside, and the increased recreational use attracted by the National Trust property, Waddesdon Manor, this is considered to be a significant negative impact.

This will to an extent be offset by the positive effects of increased leisure and recreation opportunities on the new water body. It is debatable however whether such uses are appropriate to the location, and within the context of poor and sensitive access routes.

There is little known archaeology on the reservoir site, but as with the other options, development of the reservoir and the laying of pipelines are likely to uncover features of interest. Therefore, prior to detailed route design a full desk survey of archaeology, followed up by field evaluation as necessary should be undertaken.

English Heritage will be concerned at the potential impact of the reservoir on the setting and historic landscape of Waddesdon Manor, the listed and national Trust property about 3/4 km to the north of the proposed water body. From information currently available it is thought that there will not be direct visual impacts, but concern will remain. An appropriate study should be undertaken to confirm that impacts will not be significant.

Apart from this specific item the main remaining concern will be the inundation of buildings comprising up to 7 farmsteads. These have not been evaluated at this stage, but there is significant potential for 1 or more to include listed structures, with consequent significant impact.

There are no SSSI's in the proposed outline area for the Waddesdon reservoir. However, there may be sites of local or county importance, and the precise location of any such sites would need to be determined from the county naturalist trust.

Costs

The cost of constructing a dam to impound 35,000 Ml is estimated to be £16 million inclusive of land purchase.

6.0 INTER-REGIONAL TRANSFER DEVELOPMENT OPTIONS

6.1 General

In this chapter the promising water resources development options by transfers from the Severn-Trent and Anglian regions of the NRA are considered in detail. The format for each option follows that used in Chapter 5; general outline, engineering outline, resource value, water quality, environment and costs.

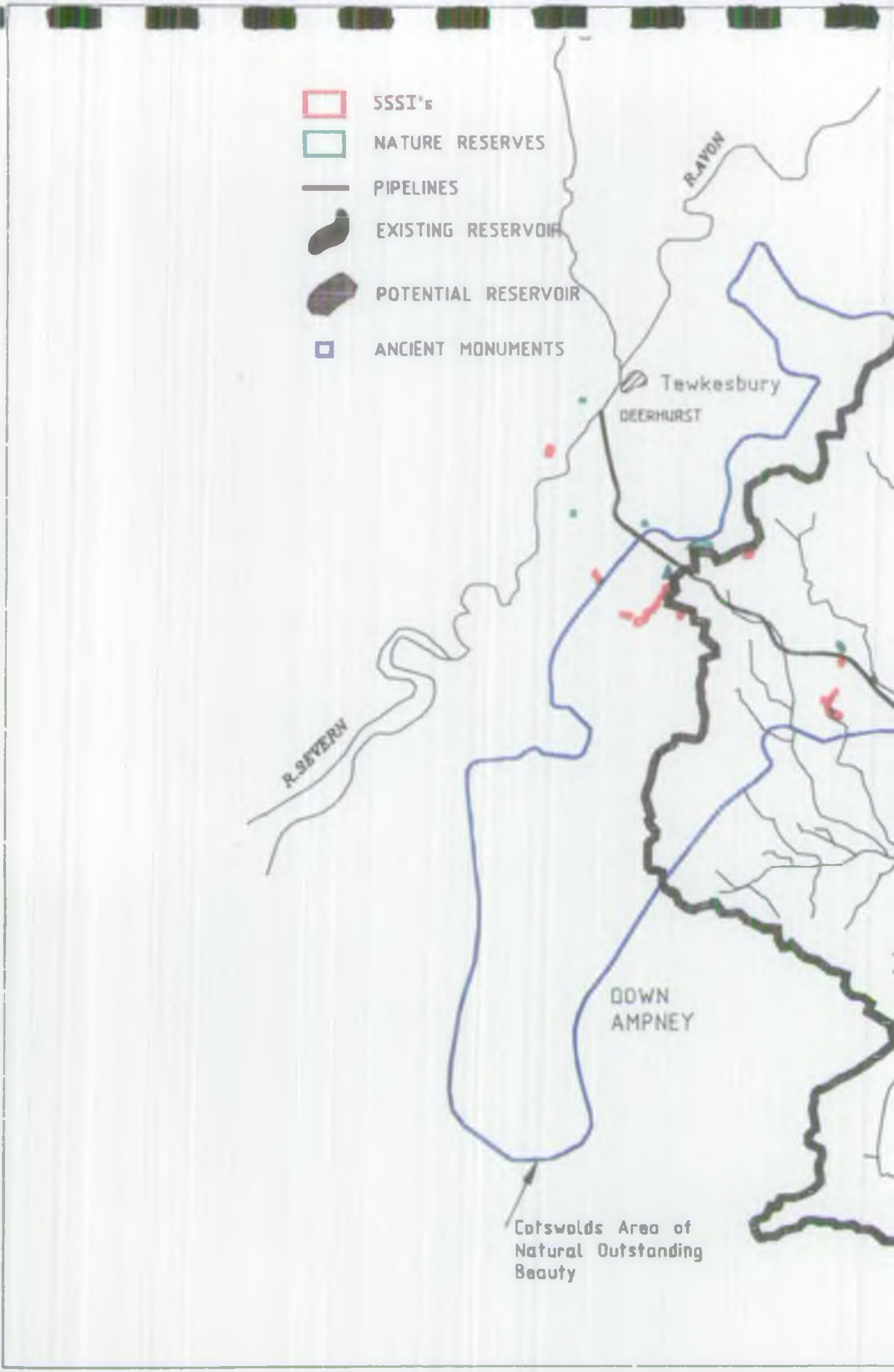
Again, resource values have been derived from operation of the NRA Water Resources Model, and are based on use to meet demands to 2021 in combination with other options.

6.2 Severn - Thames Transfers

6.2.1 General Outline

Under this option water will be abstracted from the river Severn at Deerhurst, just above Haw Bridge, and transferred into the Thames catchment to be discharged to the main river at Buscot, or directly into the Abingdon/Drayton reservoir (see Figure 6.1). The scheme will be based on existing river Severn flows without any additional regulation. Abstraction at Deerhurst, almost at the Severn estuary, will have minimal impact on the Severn catchment, subject to sufficient residual flow being passed to the estuary and for use by Bristol Waterworks Company and British Waterways Board from the Sharpness canal.

Severn-Trent NRA have given a preliminary figure for residual flow of 2000 Ml/d. This value has been used for this study but some revision may result from further evaluation by Severn-Trent NRA. At the 2000 Ml/d figure the water is typically not available for transfer in the months June to August.



SSSI's
NATURE RESERVES
PIPELINES
EXISTING RESERVOIR
POTENTIAL RESERVOIR
ANCIENT MONUMENTS
R.AVON
Tewkesbury
DEERHURST
R.SEVERN
DOWN AMPNEY
Cotswolds Area of Natural Outstanding Beauty

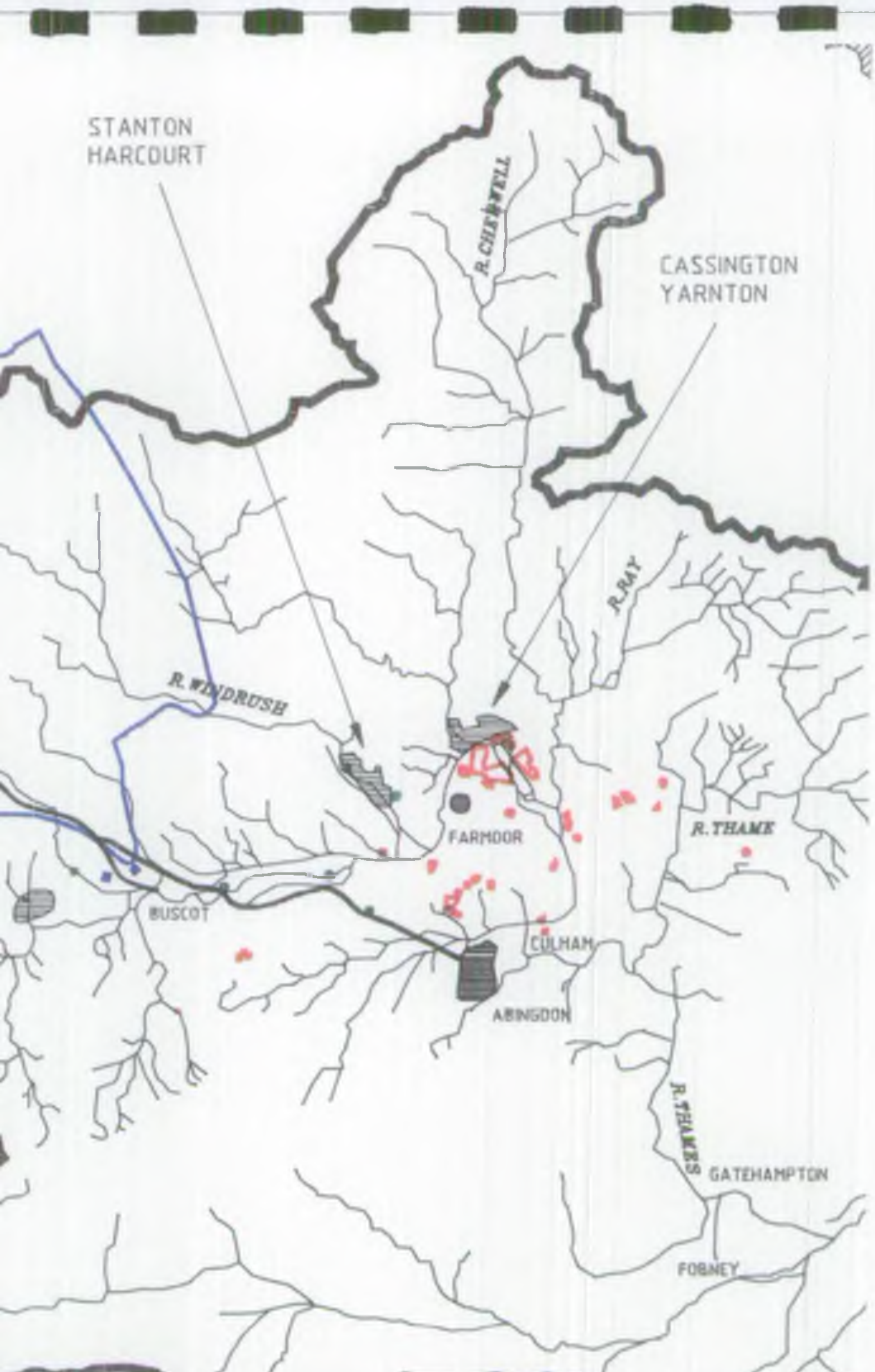


FIGURE 6.1

SEVERN - THAMES TRANSFER

Initially, maximum transfer rates of 200 Ml/d and 400 Ml/d were considered, but modelling and engineering studies have shown that only the 400 Ml/d capacity scheme need be pursued.

The transmission line will follow the route shown on Figure 6.1 and proposed by CWPU (Route 4), south of Cheltenham and crossing the Cotswolds escarpment at the Birdlip Gap, to follow the Coln Valley to Buscot.

Tunnel and pipeline alternatives for the transmission line have been considered and there appear to be no engineering, timing or cost benefits in using a tunnel in the Cotswolds section. Savings in operating costs because of reduced pumping heads are more than outweighed by the capital costs.

The transfer has a number of possible discharge points in the Thames region:-

a) discharge to the river Thames for abstraction to the lower Thames reservoirs; with transfers triggered by reservoir storage levels and flows at Teddington weir,

b) discharge to the river Thames for abstraction at Culham reach for the potential Abingdon/Drayton reservoir; with transfers triggered by Drayton and lower Thames reservoir storage levels and flows at Day's weir and Teddington weir,

c) discharge directly into the proposed reservoir at Abingdon/Drayton, thereby having no effect on the river Thames upstream of Culham,

d) discharge directly to 25,000 Ml gravel pit storage in the upper Thames, with subsequent release to the river at Buscot, thus providing regulation of summer flows (gravel pit storage is considered in Section 5.7).

Points of discharge to the river Thames were investigated by the CWPU study in some detail and it was concluded that the main river at Buscot could accommodate Severn transfer flows of up to 680 Ml/d. We have adopted a more conservative maximum transfer of 400 Ml/d based on unregulated Severn flows, which is well below the CWPU figure.

6.2.2 Engineering Outline

The components of this option comprise:-

- low lift pumping station on the River Severn at Deerhurst,

- bankside reservoir of 3 days storage capacity, for sedimentation purposes and for covering emergency closure for pollution events; storage 1200 Ml, measures will be needed to guard against inundation by flood flows.

- high lift pumping station adjacent to reservoir to lift water up Cotswolds escarpment to around 150m AOD.

- 2.0m diameter pipeline for 53km from Deerhurst to Buscot, with a high point at the Birdlip gap of 260m AOD; pumped pipeline on the northern leg, and gravity pipeline south from the escarpment,

- break tanks and high lift pumping station at around 150m AOD to lift water up to escarpment crest at 260m AOD.

- bankside reservoir of 3 days storage capacity at Buscot; storage 1200 Ml, for mixing of water and further sedimentation.

- river discharge structure at Buscot.

For the sub-option where the Severn transfer water is discharged direct to the Abingdon/Drayton reservoir, the following changes are required:

- 21km extension of the 2.0m diameter pipeline from Buscot to the reservoir,

- discharge/entry structures into the reservoir,

- no bankside storage at Buscot; however the river discharge point will be needed for emergency closure/drainage purposes.

A design period of 2 year and a 3 year construction period are anticipated. Preliminary studies, investigations and promotion of the scheme would probably require a further 5 years. It is therefore unlikely that this option could be brought into operation before 2001.

6.2.3 Resource Value

Modelling simulations show that possible Severn transfers have the following resource values for the London strategy area:-

a)	200 Ml/d transfer without Abingdon/Drayton	-	85 Ml/d
b)	400 Ml/d transfer without Abingdon/Drayton	-	135 Ml/d
c)	400 Ml/d transfer with Abingdon/Drayton	-	153 Ml/d
d)	200 Ml/d transfer without Abingdon/Drayton, but with 25,000 Ml storage reservoir in upper Thames catchment	-	151 Ml/d

The model gives the following details for operation of the various transfer sub-options:-

	Max Rate Ml/d	Mean Rate Ml/d	Years Used	Average Days in Years Used
a)	200	190	25	60
b)	400	375	32	53
c)	400	304	58	80
d)	400	293	39	117

As with the Abingdon/Drayton reservoir option, the triggers adopted in the modelling relate to the TWUL London strategy area with releases aimed at satisfying TWUL demands only.

However, regulation of the Thames allows the opportunity to meet other demands on the Thames. Released water on the way downriver to the TWUL lower Thames intakes can be abstracted for use at intakes further upstream with return to the river as effluent return, providing a multiple use while still meeting the TWUL demand. These indirect benefits are substantial and go a long way to meeting other further demands within the region.

Alternatively, the scope for overall regulation of the Thames using Abingdon/Drayton or the Severn transfer could be increased to meet all demands on the river.

6.2.4 Water Quality

Transfer of the Severn water into the Thames region has potential significance for impacts on water quality, since water from a lowland catchment reach will be discharged to the upper Thames. Effects will be least from the possible direct transfer to the Abingdon/Drayton reservoir where the Severn water will mix with Thames derived water before being released to the river.

The Severn water is richer in nutrients than the upper Thames water, and could possibly increase the risk of eutrophication and algal blooms in the reservoir.

We have examined the possible water chemistry resulting from a range of blends of Severn (Haw Bridge) water and Thames (Buscot) water (see Appendix 4). The quality of both waters is very similar and there are not expected to be any marked changes in the water quality in the upper Thames as a result of the transfer. Bankside storage of the Severn water at Deerhurst and Buscot will assist in reducing the rather higher suspended solids content of the Severn water before discharge to the Thames.

Contingency planning for control of the intake at Deerhurst in response to pollution incidents would have to be carefully considered in the design of the scheme.

6.2.5 Environment

a) Construction

Significant impacts will result from the construction of the scheme. Care will be required in design, planning and construction of all of the scheme elements to minimise the impact, particularly in the nationally designated Area of Outstanding Beauty in the Cotswolds Hills.

Landtake for bankside storage at the Severn abstraction point at Deerhurst and at the Thames discharge point at Buscot will be considerable, each involving up to 40 ha of bunded reservoir. Since both will be in the floodplain, the impact on flood plain management and flooding will need to be investigated.

The conservation constraints of SSSI's along the proposed pipeline route are shown on Figure 6.1. There do not appear to be any significant problem areas where specific routes cannot be established. Construction will have significant landscape and visual impact in the short term, but with proper restoration there should be no long term residual effects.

The landscape around Buscot is sensitive and the discharge infrastructure will need to be sympathetically designed and constructed.

Tunnelling is likely, on balance, to create rather fewer landscape and visual impacts overall, and thus avoid impacts on nature conservation features on the surface. However, engineering, construction time and cost comparison suggest a pipeline. More detailed studies at feasibility level would be required to confirm this.

The possible pipeline extension to a new reservoir at Abingdon would again give rise to significant impact in the short term in terms of landscape, amenity, noise, disturbance and traffic movements. However, a positive landscape and visual effect would result from this direct transfer through the avoidance of potentially detrimental works at Buscot.

There is a high potential for the development to encounter archaeology of a number of periods. Only broad route corridors have been established at present and these will need to be refined and narrowed according to other environmental constraints and a detailed desk study then undertaken to identify known archaeological features in proximity to the route.

Loss or fragmentation of habitats will be the principal ecological effects and an early assessment of Sites of Special Scientific Interest lying within 5 km of the proposed route has been carried out. Wherever possible the pipeline should avoid sites of ecological importance that have national or regional status. Furthermore, attempts should be made to avoid features of natural history interest such as ancient woodlands and unimproved meadows. At present the tentative alignment of the pipeline would affect 2 SSSI's and possibly a third depending on the extent of landtake needed by the works, but alternative alignment could be found during the design phase.

Construction work may result in temporary disturbance to animal communities and care will be needed to minimise these. Of particular note are impacts on protected species such as Badgers and Great Crested Newts. Where effects are temporary, mitigation measures can be put in place in many instances. Revegetation strategies will be necessary after construction. Details of such approaches are widely available and should be recommended as part of environmental mitigation measures.

b) **Operation**

CWPU were concerned that discharge to the river at Buscot would possibly effect drainage of river-side agricultural land, with loss of land or lowering of quality. NRA Land Drainage department are of the opinion that impacts are unlikely to be significant in policy terms. As mentioned with reference to Abingdon reservoir, the importance of protecting agricultural land has reduced significantly and in fact, the opportunity for nature conservation gains in the form of wetlands and water meadows along the river may be a positive impact of increased flows in the upper Thames. It should be noted however, that compensation claims may be made in certain circumstances by farming interests. The potential significance of these needs to be assessed further.

The impact of the transfers on aquatic biology depends principally on the magnitude and frequency of the transfer volume and the quality of water from the Severn.

The flow condition produced by a transfer of 200 Ml/d will be within the natural variation already experienced by the river (see Appendix 2). However, the monthly mean flow at Buscot would be doubled in August and

September. Transfer rates of 400 Ml/d at Buscot with storage would result in flows exceeding monthly maximum flow in July, August and September and approaching monthly maximums in June, October, November and December.

There have been few studies pertaining to the effects of catchment transfers on the aquatic biology of the donor and recipient rivers. Most discussions of the ecological and fisheries effects of the river transfer have taken place at the planning stage, using predictions with no post-transfer data to confirm the predicted effects. No attempt to carry out audits on existing UK transfer schemes are known.

The most obvious effects will be long term increases in flow velocity, changes in water chemistry and short term velocity fluctuation which may adversely affect both slow and fast flow fish, invertebrate and macrophyte species.

Changes in flow velocity could bring about changes in fish populations even though the maximum velocity induced may well still be within the pretransfer maximum during flood flows. The latter occur only temporarily whilst transfer flows are more long term.

Flow velocities affect invertebrate fauna through shifting of bed material, and destruction of fauna, or its occlusion by siltation, downstream displacement of certain species, and alteration in the texture of the river bed. This could result in subtle changes in species composition, favouring those with higher velocity preferences. It could also result in the removal of detritus and detritus feeders. The effects of changing flow velocity on river beds is complex and depend upon a number of different factors which need further research.

Sudden introduction and cessation of large intermittent transfer flows are thought to be particularly damaging as this could affect both slow and fast flow species. Migratory salmonids have the most critical flow requirements; non-migratory salmonids and coarse fish are less susceptible.

Obviously the rate at which the transferred flow is introduced into and arrested from a recipient river is important. It has been suggested that flow alteration should not exceed rates normally occurring in natural floods and build up and die down should occur over 24 hours.

Angling is thought to be the only recreational activity likely to be affected by the proposed scheme, for the reasons outlined above.

Benefits of increased flows include maintaining flows in dry weather periods which would be beneficial to aquatic fauna, fisheries and anglers alike. In addition there may be benefits to Thames-side meadows.

Possible biological effects of changes in water quality include effects on salmonids whose numbers have increased in the Thames over recent years. Changes in water quality could alter the homing response of upstream migratory salmonids. The 'homing' of migratory fish such as salmon and sea trout to their natal rivers and streams to spawn could be affected by inter-basin transfers, as the changes in water quality could add a 'foreign smell' if in operation during the smolt or adult migration period. If transfer is continuous and occurs all the year round, homing would not be affected.

One factor of particular relevance to this transfer option is that of algal production. The Thames and Severn have similar algal floras, and both rivers can produce high spring densities. Introduction of Severn water containing high densities of algae from the lower end of the catchment into the upper end of the Thames catchment, could speed up the time in which maximum population levels were reached and extend the zone of maximum density further upstream. Recent research by the Institute of Freshwater Ecology (IFE)(Reynolds, pers comm) supports this concept.

Due to canal systems linking the Thames to the west, the biological differences appear to have diminished. NRA Fisheries department do not consider this to be a major concern.

The Ely-Ouse transfer scheme in Anglian region has resulted in the river-to river-transfer of the predator fish zander. However this fish is already present in the Thames and fish species are similar in the Thames and Severn catchments, therefore transfer of undesirable fish is unlikely to present problems for the proposed Severn transfer.

Transferring water from the Severn and placing it into the Abingdon/Drayton reservoir rather than either directly into the Thames at Buscot or into storage at Buscot would appear to be preferable from an environmental point of view. The upper Thames is a relatively unspoilt part of the Thames river (although suffering from the effects of effluent from Swindon) and it would be difficult to transfer more than 200 Ml/d without resulting in significant adverse impacts. From a biological point of view putting water from the lower end of the Severn in the middle reaches of the Thames is preferable to placing it into the upper reaches. This will reduce retention time and thereby reducing the possibility of algal blooms. In addition the overall quality of the lower Thames is closer to that of the lower Severn due to the presence of effluents and therefore there is less likelihood of impact on invertebrates and fisheries.

6.2.6 Costs

The capital and operating costs associated with Severn-Thames transfers are as follows:-

		Capital Cost £M	Operating Costs £M/annum
a)	200 Ml/d transfer without Abingdon/Drayton	76	1.3
b)	400 Ml/d transfer without Abingdon/Drayton	155	1.5
c)	400 Ml/d transfer with Abingdon/Drayton	188	2.2
d)	200 Ml/d transfer with Gravel Pit Storage	118	1.6

6.3 Anglian-Thames Transfers

6.3.1 General Outline

Key components of the future water resources strategy option in Anglian region are a series of southward river basin transfers based on development of water from the River Trent, as shown on Figure 6.2.

Transfers to Thames region have been included in the Anglian study and these have been considered in this project. Initially, the Trent transfer amount under consideration was set at a maximum of 600 Ml/d of which 200 Ml/d was earmarked for Thames region. The Trent transfer has recently been increased to 700 Ml/d for our planning purposes to allow a 300 Ml/d transfer to Thames.

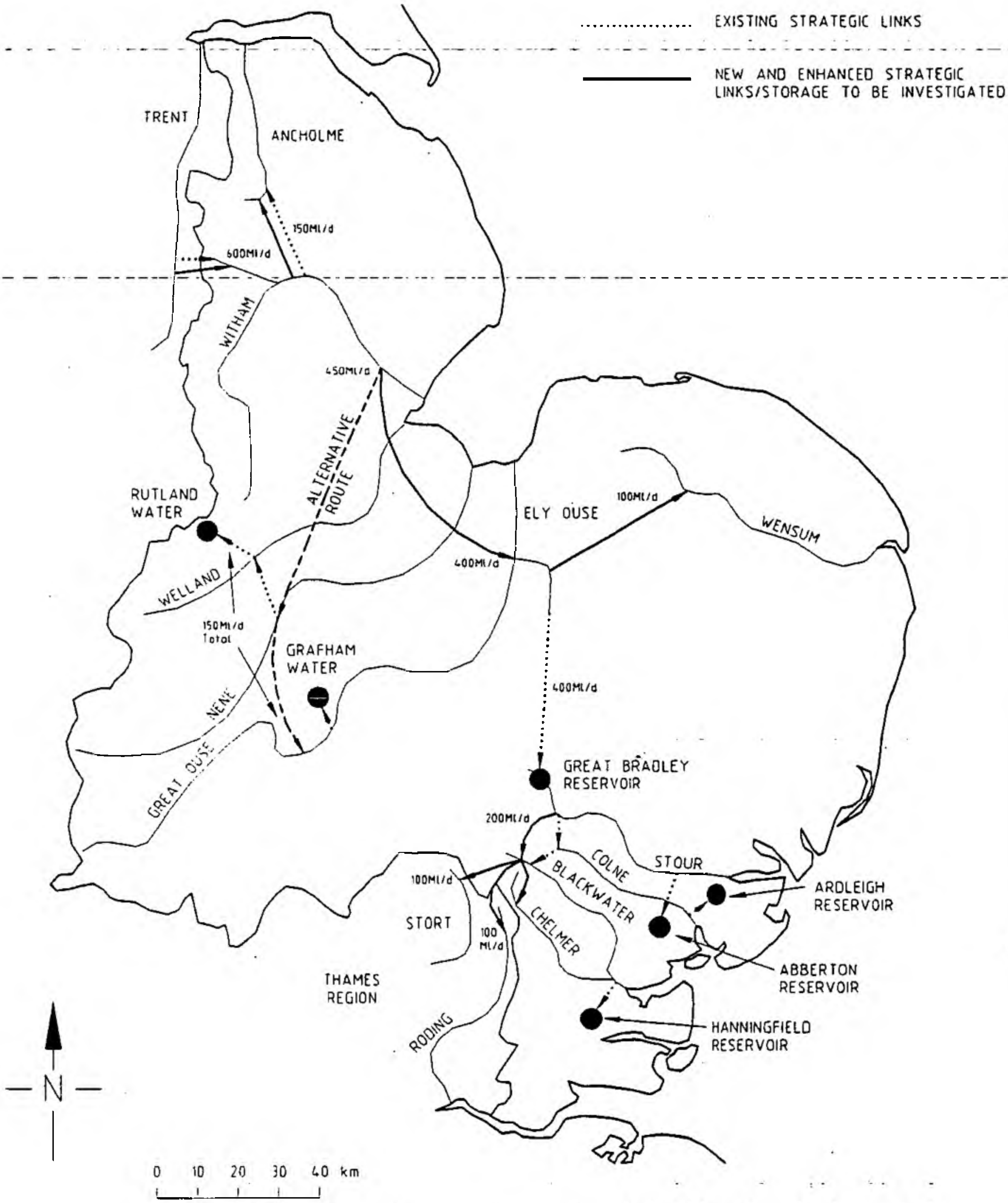
It has become apparent during our study that other significant demands, for abstraction and in-situ requirements, have arisen on the Trent and that transfers are unlikely to be possible in the period June to August. This has encouraged the inclusion of storage within this transfer option.

Points of entry into the Thames region depend upon which of the alternative transfer links from Great Boston on the Witham to Denver sluice on the Great Ouse are pursued by Anglian region NRA (see Figure 6.2). Adoption of the western link via the rivers Welland and Nene to the Great Ouse will allow the opportunity to transfer water into the middle Thames region, whereas the direct fens link restricts possible transfers to those in the east, via the Ely-Ouse-Essex system, perhaps with a reservoir at Great Bradley providing storage.

The potential yield of Great Bradley from existing Ely Ouse resources is provisionally estimated by Anglian Region NRA at around 200 Ml/d.

Assuming the western Anglian route, is adopted, then possible transfers (see Figure 6.3 and 6.4) include:-

FIGURE 6.2



STRATEGIC OPTIONS UNDER CONSIDERATION WITHIN ANGLIAN REGION

a) raw river water from the Great Ouse downstream of the Anglian Region NRA discharge, transmitted by pipeline to a reservoir at Waddesdon, near Aylesbury, with discharge to the river Thame; a transfer of 100 Ml/d has been used in this study. with a maximum release of 200 Ml/d to the Thame.

b) additional use of Grafham storage, based on the Trent supported discharge to the Great Ouse, with the supply of treated water to the Three Valleys Water Company increased by an assumed 100 Ml/d.

c) increased supplies available to the Ely Ouse-Essex system, perhaps incorporating a pumped storage/impounding reservoir at Great Bradley on the River Stour, allowing an assumed transfer of up to 200 Ml/d into the Thames region via significant western extension of the present river Stour to river Blackwater transfer scheme, thereby supplying Essex Water Company and TWUL.

d) potential direct supply of treated water from Great Bradley reservoir, up to 200 Ml/d, possibly serving Three Valleys Water Company, Essex Water Company, and TWUL; supply to Essex Water Company could release the present 91 Ml/d bulk transfer to Chigwell by TWUL.

The Great Bradley reservoir is under detailed study in the Anglian region strategy review. We have not sought to include it in our consideration therefore, but initial indication of feasibility and potential should be available by the middle of 1992 and should be taken into account in any further consideration of transfers from Anglian region.

For the purposes of the present study we have conservatively assumed that there is no regulating storage in the eastern transfer route and that transfer is not possible in the period June to August.

Transfers to Thames region via a pipeline extension of the Ely Ouse-Essex scheme could be carried out in a number of ways including:-

a) discharge to the river Chelmer for abstraction by Essex Water Company for Hanningfield reservoir, or

b) discharge of 100 Ml/d to the river Roding for abstraction by Essex Water Company at Chigwell; releasing the 91 Ml/d TWUL bulk supply, and

c) discharge of 100 Ml/d to the river Stort for abstraction by TWUL in the Lee Valley; or

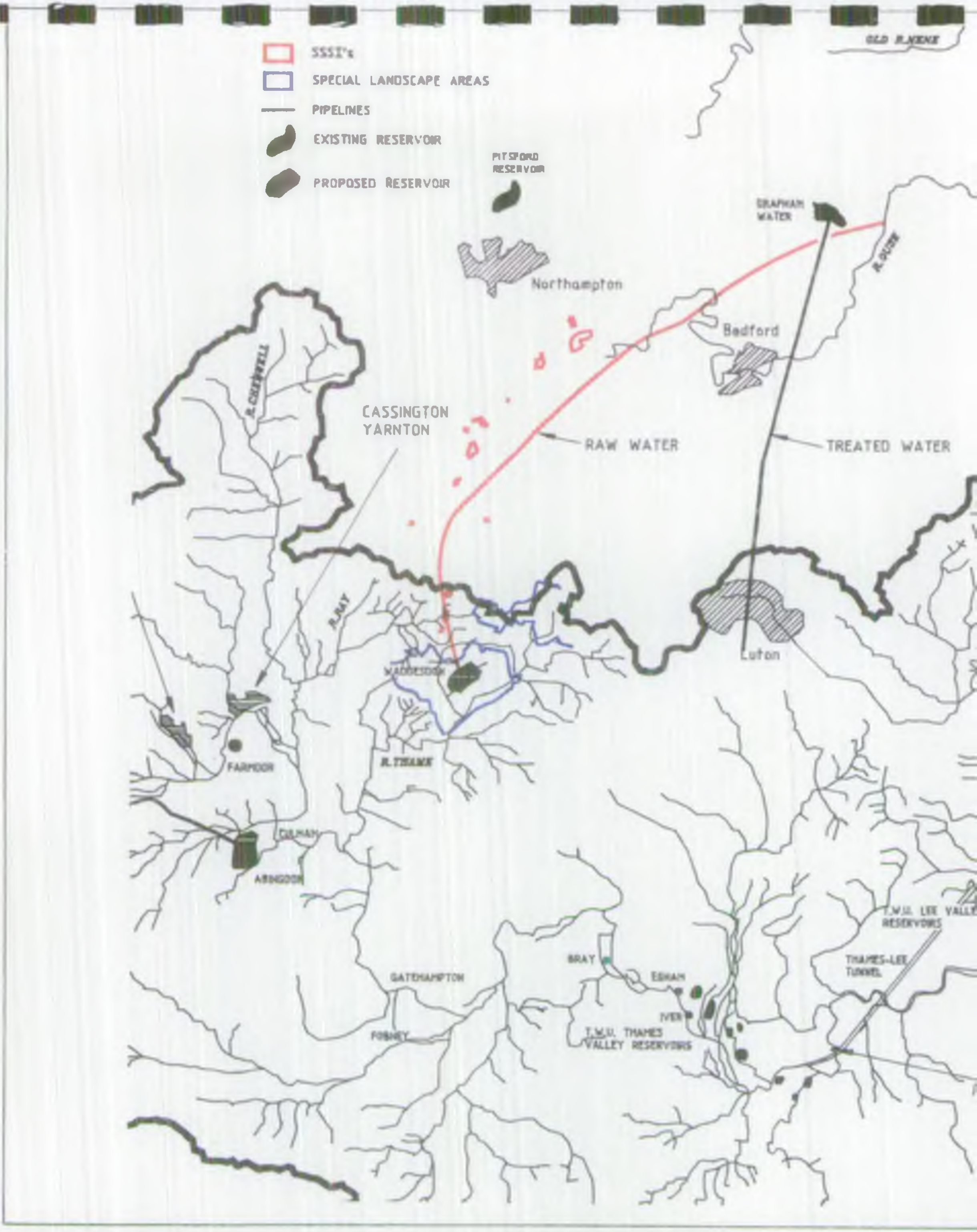
d) discharge of 200 Ml/d to the river Stort for abstraction by TWUL in the Lee Valley with continuation of the 91 Ml/d bulk supply to Essex Water Company.

6.3.2 Engineering Outline

a) Transfer to Thame (see Figure 6.3)

This sub-option involves the following works:

- intake on the Great Ouse, below or associated with the discharge point of the Anglian region transfer,
- pumping station adjacent to intake, maximum rate 100 Ml/d
- 1.0m diameter pipeline for 73 km to discharge to a reservoir at Waddesdon,
- 17m high dam, and saddle dam at Waddesdon providing usable storage of 30,000 Ml,



OLD R.NENE
SSSI's
SPECIAL LANDSCAPE AREAS
PIPELINES
EXISTING RESERVOIR
PROPOSED RESERVOIR
PITSFORD RESERVOIR
GRAFHAM WATER
R.OUSE
Northampton
Bedford
R.CHERWELL
CASSINGTON
YARNTON
RAW WATER
TREATED WATER
R.RAY
Luton
WADDESDON
FARMOOR
R.THAME
CULHAM
ABINGDON
T.W.U. LEE VALLEY RESERVOIRS
THAMES-LEE TUNNEL
BRAY
EGHAM
GATEHAMPTON
IVER
T.W.U. THAMES VALLEY RESERVOIRS

FIGURE 6.3

ANGLIAN TRANSFERS TO THAME
AND FROM GRAFHAM WATER

- gravity pipeline of 1.4m diameter from Waddesdon reservoir to the river Thame in the Waddesdon to Shabbington reach, passing through the Shabbington gauging station, maximum release 200 Ml/d,

- possible minor channel works to the river Thame.

- measures to aerate/circulate the reservoir waters to prevent stratification and eutrophication.

The reservoir release will be triggered by the storage levels in the lower Thames reservoirs, the needs of other intakes, and flows at Teddington weir.

Details of the proposed reservoir were presented in section 5.7; the site has been studied in some detail in the past but for a much larger reservoir.

As well as regulating the Thame/Thames, the reservoir could also be used for direct supply to Aylesbury and its environs, which has a total demand of 40-50 Ml/d, including those met from existing sources.

This sub-option has the potential of general benefit to the lower Thames, with augmented flows improving the character of the river, whilst meeting sequential demands at all intakes down to Teddington weir. The other sub-options are geared to providing water to meet demands at specific locations in North and East London, and effluent return will generally be lost to the tideway.

b) Direct Supply from Grafham Water (see Figure 6.3)

In this sub-option the works consist of duplicating the existing infrastructure of Three Valleys Water Company and of the owner/operator of Grafham Water, Anglian Water Services.

Work required would include:-

- expansion of pumping station on the Great Ouse, and transfer pipeline to Grafham Water,

- additional low lift pumping station and treatment plant for 100 Ml/d abstraction from Grafham Water,

- a 1.0m diameter treated water pipeline paralleling the 2 existing Three Valley Water Company pipelines to Luton, transmitting 100 Ml/d.

We stress that this sub-option is based on assumed capacity for greater use of Grafham Water. The potential for operating Grafham Water to provide further supplies to Three Valleys Water Company (and Anglian Water) has not been studied, and work is required to establish the potential yield based on the Trent-supported flows.

c) **Transfer via Extended Ely Ouse-Essex Scheme (see Figure 6.4)**

Common works required for all the variants of this sub-option are:-

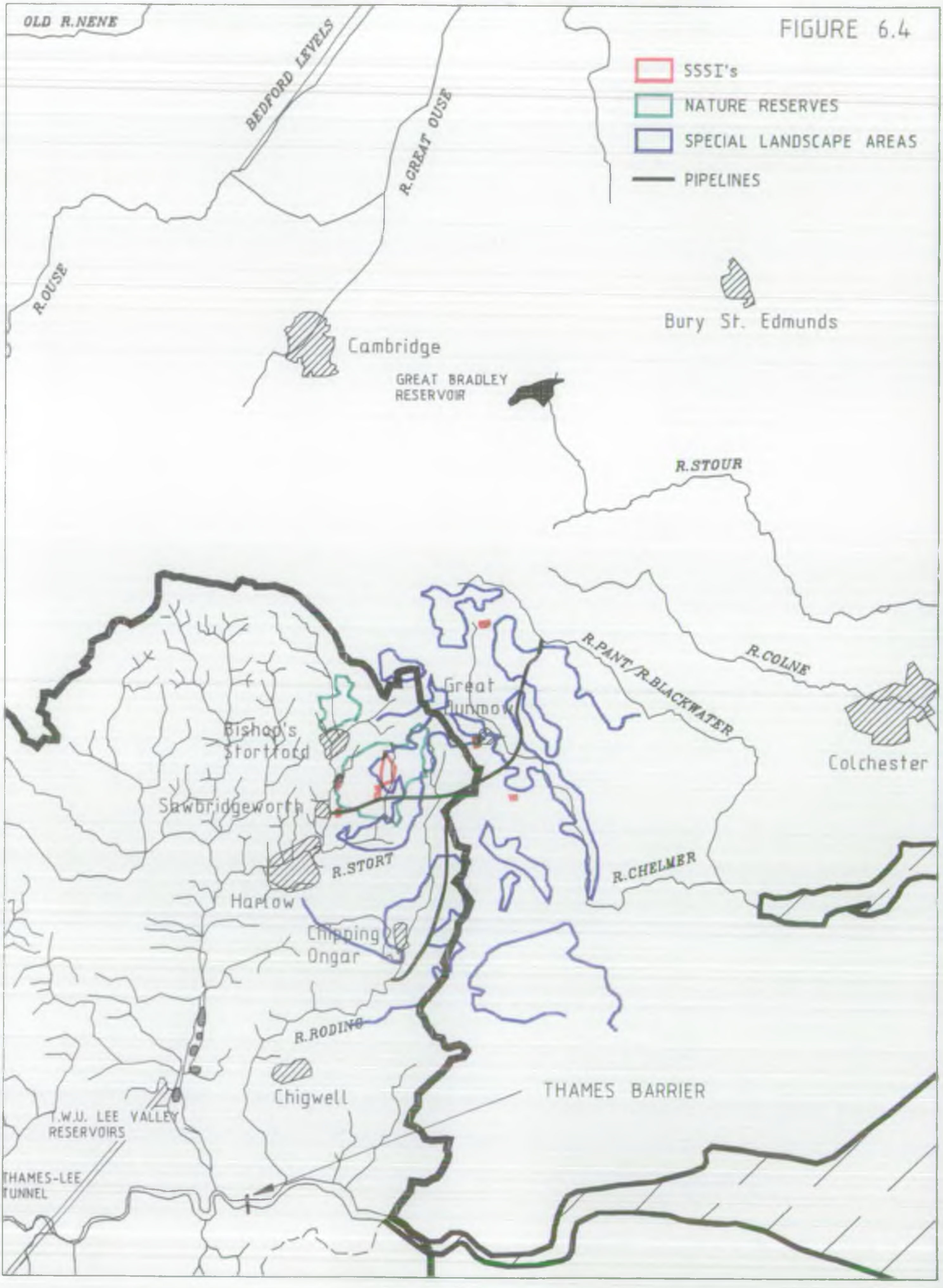
- increase in pump capacity at Kennett Pumping Station by 200 Ml/d,

- increase the transmission capacity by 200 Ml/d between Kennett Pumping Station and Kirtling Green (or Great Bradley reservoir) by the construction of a 1.4m diameter main,

- increase in intake pump capacity at Wixoe Pumping Station on the Stour,

- improve hydraulic regime of River Pant from Great Sampford to Great Bardfield.

ANGLIAN TRANSFER ELY OUSE-ESSEX SCHEME



Discharge of 200 Ml/d to the river Stort would involve:

- intake and pumping station at Great Bardfield on the river Pant, for 200 Ml/d,

- 1.4m diameter pipeline for 28 km from Great Bardfield to the river Stort at Sawbridgeworth,

- river discharge structure,

- possible river training works and alterations to navigation structures.

Discharge of 100 Ml/d to the river Stort and 100 Ml/d to the river Roding would involve:

- reduction of Stort transfer pipeline beyond the Roding to 1.0m diameter,

- 1.0m diameter pipeline for 17km to a discharge point on the river Roding below High Ongar,

- possible moderate river training works downstream of the discharge point,

- river intake/pumping station near Chigwell.

The river Roding has much lower flows than the other rivers for which transfers are being considered in this study. The very significant potential impact of the 100 Ml/d transfer on the Roding flow regime are illustrated in Appendix 2, and would be likely to necessitate channelisation from the discharge point to Chigwell. We consider that the discharge pipeline length required to release water into a suitable receiving channel and the associated costs together with environmental impacts are such as to make a direct supply by pipeline to the Essex Water Company at Chigwell, probably a preferable alternative.

All of the sub-options involve common work from the river Trent to the river Witham, and from the Witham to the Great Ouse as shown on Figure 6.2.

6.2.4 Resource Value

Results of the resource simulation modelling has shown the Anglian transfer sub-option to have the following resource values:

Transfer to Thame via Waddesdon reservoir- 100 Ml/d flow transfer and 200 Ml/d augmentation from reservoir	103 Ml/d
Transfer to Stort of 100 Ml/d	50 Ml/d
Transfer to Roding of 100 Ml/d (assumed pipeline to Chigwell)	91 Ml/d (offset to TWUL bulk supply)
Direct supply from Grafham	100 Ml/d (assumed)

For the Thame sub-option the 100 Ml/d transfer was in use for 56 years out of the 70, with transfer periods averaging 120 days within a maximum of 274 days. Augmentation to the Thame at 200 Ml/d was in use for 45 years out of the 70, with a maximum release period of 214 days and an average of 104 days over the 45 years.

6.3.4 Water Quality

Trent river water quality has improved dramatically over the last 20 years as a result of a major clean up programme instigated for the catchment. Nevertheless, it still drains a heavily urbanised and developed catchment and water quality reflects this. It is however, suitable as a feedwater for public water supply treatment plants.

The present introduction of Trent Water into the Witham catchment does not appear to have led to any problems with respect to adverse water quality changes. It must be said however, that there do not seem to have been surveys or studies into the chemical, biological and other effects of the transfer.

By the time the Anglian transfers reach the Thames region, by whatever route, the water will have passed through at least two and possibly up to five rivers, with attendant dilution, blending and inter-reaction. It is not possible at present, therefore, to make any realistic prediction of the quality of raw water that will be transferred to the Thames region, other than to say it should be superior to the original Trent derived water.

6.3.5 Environment

In this study we have only considered the affects of the possible transfer variants on the environment in the Thames region. Only the final transfer links into Thames region, as given in the engineering outline, are discussed here.

Many of the broad impacts previously identified within the Abingdon/Drayton reservoir and Severn transfer option are equally applicable to this option in terms of the laying of pipelines and possible construction of reservoirs. Environmental considerations of the latter are presented in section 5.7.

The chief difference between this previous transfer option and those considered here is in terms of the scale of the receiving river. The rivers Thame, Stort and Roding are much smaller than the Thames and therefore have less ability to absorb transfers without significant change to their own character. This is applicable primarily to in-river characteristics, but is to an extent also relevant to broader environmental elements.

a) **Construction**

The broad impact of pipelines and associated information provision will be similar to those identified for the Severn-Thames transfer option. Similar local impact on landscape, amenities, recreation, agricultural operation and drainage will arise, but these will largely be of a temporary nature and can be satisfactorily mitigated through appropriate engineering solutions.

As with all pipeline options, careful evaluation of archaeological impact potential will be necessary and mitigation measures taken as appropriate.

i) **Thame Transfer Sub-option (see Figure 6.3)**

The proposed pipeline route has been set out on a broad basis as shown on Figure 6.3. While the appropriate route does not directly pass through any SSSI's the Figure shows there are a number in this 10km corridor. In the vicinity of Waddesdon the pipeline will pass through an Area of Attractive Landscape identified in the Buckinghamshire Structure Plan. These sites will need to be carefully considered in the final alignment of the pipeline.

ii) **Stort-Lee Transfer Sub-option (see Figure 6.4)**

For this sub-option the pipeline route would pass through a number of Special Landscape Areas including the Stour Valley SLA, Pant Valley SLA, Chelmer Valley SLA and the Hatfield SLA. It is anticipated that these county-level designation areas would not be subject to major impacts after construction was complete. The areas are identified in Figure 6.4. These landscapes are all sensitive and the high potential for longer term negative impacts requires early mitigation by very careful and detailed design of routes, if the option is pursued.

The areas through which the pipeline will pass are uniformly Grade 2 of the Agricultural Land Classification and are under intensive cultivation. Similar issues of largely temporary disturbance of farming practices will arise as for option discussed earlier.

The route would also pass through the Stort Valley Nature Conservation Zone identified in the Essex Structure Plan. This is a policy designation designed to help protect the Hatfield Forest SSSI and this is identified on Figure 6.4. It would be essential for the pipeline to avoid this zone.

The option has been considered on the assumption that no channel improvements will be required on the Stort or Lee rivers themselves. Consideration of the scale of the impact of transfers of 100 Ml/d and 200 Ml/d on the river regime below Bishops Stortford (see Appendix 2) indicates that additional flow of 200 Ml/d could probably not be accommodated without channelisation and possibly works to the many navigation structures. For this reason it is proposed that this sub-option is not pursued further. In the event that channel improvement or even channelisation were required, which requires further consideration, significant impacts would result, which would need very careful evaluation. Such impacts would almost certainly be strongly resisted by the various environmental organisations such as the Countryside Commission and English Nature.

It is not considered that this option will give rise to significant recreation and amenity impacts, provided pipeline routes through Hatfield Forest, in particular, are avoided, as this is a popular recreation area and an historic landscape. There may be positive impacts resulting from increased flows in the summer through the Lee Valley Park in particular which is a regional attraction, centred around the river and gravel pit network.

There are several SSSI's in the 10 km pipeline corridor and these are illustrated on Figure 6.4. These are from north to south West Wood, High Wood, Garnetts Wood, Hatfield Forest, Thorley Flood Pound and Sawbridgeworth. Other sites of nature conservation should be recorded prior to finalising a route.

iii) Roding Transfer Sub-Option (see Figure 6.4)

Very similar comments apply to this sub-option as for the Stort sub-option, as the proposed pipeline runs through similar countryside including part of two Special Landscape Areas. Similar potential impacts would arise.

As with the Stort sub-option the agricultural land involved is uniformly Grade 2 - Good Quality, and similar comments apply.

The route passes through the south western edge of the Hatfield SLA and therefore similar potential impacts would arise as for the Stort sub-option. The route would also pass through part of the Roding Valley SLA. The higher ground away from the river is well wooded and pipeline through this vegetation would require very careful treatment in order to minimise long term impacts.

There are several SSSI's in the 10 km pipeline corridor and these are illustrated on Figure 6.4.

Overall, the same comments apply as to the Stort sub-option, apart from the fact that there is an intrinsic advantage to this sub-option in that it avoids channelisation of the Roding upstream of High Ongar. As discussed earlier however, the probable impact of the 100 Ml/d transfer on the river regime, even below Ongar, is likely to require channelisation and we recommend serious consideration of extending the transfer pipeline direct to Chigwell.

In terms of archaeology and history similar comments apply as for other pipeline options, but it should be noted that greater potential exists for significant impacts due to the extensive Roman settlement and road building in the area.

(iv) Increased use of Grafham Water (see Figure 6.4)

Impacts associated with new treatment, additional pumping works at Grafham Water and a further treated water pipeline into the Thames Region are likely to be small in scale involving replication of existing facilities.

b) Operation

i) Thame Transfer sub-option (see Figure 6.4)

The maximum transfer rate into the Thame from the Waddesdon reservoir would be 200 Ml/d. This transfer rate would be within the river's maximum flows in all months except July and September. It does however represent at least a doubling of mean flow in the summer and autumn months. The effects of this increase in flow are similar to those defined under the Severn transfer options. Benefits would include reasonable summer flows during periods of low flow. Impacts on fisheries and macroinvertebrate fauna and macrophytes will be similar to those defined for the Severn transfer. However, the Thame does experience problems with siltation and excessive weed growth and therefore an increase in flows may have positive effects on present siltation patterns.

The biological and chemical effects of this transfer are difficult to predict in view of the sequence of interbasin transfers and will need further consideration. It will be necessary to fully consider water quality impacts on aquatic biology and fisheries when further information becomes available.

The Thame is an EC designated Cyprinid fishery in accordance with the EC Directive 78/659/EEC from Cuddington stream to the Thames, although both fish and invertebrate populations are influenced by the poor performance of the Aylesbury STW. The BMWP scores in general fail to meet those predicted. However water quality improves further downstream and at Dorchester bridge (SU 57909390) actual scores meet and exceed those predicted. Releases under the proposed transfer could significantly improve conditions.

ii) Stort-Lee Transfer Sub-option (see Figure 6.4)

The Stort fisheries largely comprise roach, chub and pike and a number of stretches are EC designated Cyprinid fisheries 78/659/EEC. Proposed transfer rates are expected to be in the region of 100 Ml/d and will be transferred to the Stort downstream of Bishops Stortford. This would mean that maximum monthly flows would be exceeded for 7 months of the year, which could result in significant impacts occurring. The river downstream of Bishops Stortford becomes formalised in the shape of a navigation channel, to the confluence with the River Lee, although interspersed along the navigation channel are remnants of the old river course. Habitat availability along this stretch of the river is extremely poor which has already had significant effects on the fisheries. Poor flow as a result of large numbers of locks between Bishops Stortford and the river Lee has backed water up resulting in increased siltation and has also resulted in adverse impacts upon fisheries. It is unlikely that increased flows will have a positive benefit on siltation patterns, if the locks remain in place.

The upper part of the catchment between Langley and Stanstead Mountfitchet is a small river and is suffering from low flows, drying up in places during summer. Although increased flows would benefit this stretch of the Stort the natural channel does not have the capacity to accommodate 100 Ml/d.

The BMWP scores at all stations failed to meet the predicted scores in 1991, however were particularly poor around Bishop Stortford where the predicted score was 155 and actual scores ranged from 40-95.

The changes to water quality and consequential effects on aquatic biology are difficult to predict in view of the sequence of interbasin transfers.

Benefits of increased flow in the summer will depend on the extent of low flows if any, currently experienced by the river downstream of Bishops Stortford.

Transfer of 200 Ml/d to the river Stort immediately below Bishop Stortford will not be possible without channelisation, and changes to the navigation structures, and in view of this it seems preferable for the potential 100 Ml/d supply to Essex WC to be supplied via another transfer option.

iii) Roding Transfer Sub-option (see Figure 6.4)

The Roding is an EC designated Cyprinid fishery from source to Brookhouse Brook in accordance with EC Directive 78/659/EEC. The typical Roding fishery comprises a mixed chub, dace, and roach population. The biotic class of the Roding varies along this stretch but is largely classified as Biotic C. Many of the BMWP scores fail to meet those predicted.

The transfer would not be discharged to the Roding north of High Ongar, as the existing capacity north of this point is such that significant channel modifications would be required in order to accommodate flows up to 100 Ml/d. Mean monthly flows at High Ongar between 1963/1991 range from a high of approximately 100 Ml/d in January to a low of 10 Ml/d in June. Hence a transfer volume of 100 Ml/d could represent up to a ten-fold increase in the Roding discharge at Ongar. This will have significant implications for downstream fisheries and the overall character of the river.

Possible impacts would include, displacement of stocks, scouring and alteration of spawning areas, and alteration of ecological regime with a consequential shift in fish species composition.

The effects of chemical change on aquatic biology will depend on a number of factors including the nutrient status of the Trent-supported water from the Ely Ouse-Essex Scheme. Much of the River Roding is classified as NWC Class 1b although there are stretches of class 2. Water quality is poor due to runoff of agricultural fertilisers and pesticides. Introduction of Trent-supported water (originally abstracted form a Class 2 river) may give rise to permanent deterioration in water quality and resultant effects on fish population. However, this is still very speculative at this stage, and would need detailed consideration at a later stage.

In view of the likely overwhelming changes to the flow regime of the lower Roding, perhaps with a need for channelisation to accommodate the flows we consider it would be preferable to pursue the feasibility of transfer to Essex Water Company via the river Chelmer and Hanningfield reservoir or otherwise by pipeline to Chigwell.

iv) **Increased Use of Grafham Water (see Figure 6.4)**

Impact during operation of this sub-option will depend on the possible changes in the characteristics of Grafham Water in terms of greater and more frequent fluctuation of level. These may be particularly noticeable in terms of views of the reservoir, with extensive areas of muddy foreshore visible at low water times.

Such impacts have been raised as significant by objectors in relation to other reservoirs, operating and proposed, in the country. Therefore it is important that the amount of fluctuation be identified at an early stage of project design in order to address visual impact issues.

Grafham Water is intensively used for leisure and recreation, and forms a recreation resource of regional significance. Activities represented on and around the water body include sailing, windsurfing, fishing, cycling, walking and birdwatching. Future plans include the provision of a pleasure boat, and the establishment of a nature trail network.

Impacts of the proposed scheme on the recreation aspects of the site will be most significant in terms of their effects on water level within the reservoir. The activities most likely to be affected are sailing, windsurfing and fishing. These will be affected primarily in terms of ease of access to the water itself with the extensive muddy foreshore potentially causing problems for all these users in the event of significant drawdown.

6.3.6 Costs

All of the Anglian transfer options depend on regional common works from the Trent to the Witham and from the Witham to the Great Ouse. Eastern transfers via the Ely Ouse-Essex system will involve additional works partly aimed at satisfying demands within Anglian region, and partly for transfers into Thames region.

Studies are underway by Anglian region NRA to arrive at engineering outlines and costs for the works required within their area. The results of these studies will only be available towards the end of 1992, by which time the likely regional development options will be better defined. Interim results will be available by the middle of 1992.

For the purpose of this study we have made a best estimate of costs of the Anglian Region works as discussed earlier, in order to arrive at figures for comparison with the other Thames' options, but we are aware that more detailed and exact cost estimates will soon be available.

For each of the Thames transfer sub-options the present cost of the Anglian region transfer works has been included. The contributions to capital costs assumed to be attributable to NRA-TR for each of the Trent-supported Thames transfer sub-options are as follows:

Transfer of 100 Ml/d to Thame:

-	Trent to Great Ouse Pumping Station	43%
-	Great Ouse to Thame	100%

Transfer of 200 Ml/d to Stort

-	Kennett PS to Stort	100%

Transfer of 100 Ml/d to Stort + 100 Ml/d from Grafham

-	Kennett PS to Gt Sampford	50%
-	Gt Bardfield PS to Stort	100%
-	Grafham to Luton	100%

Transfer of 100 Ml/d to Stort + 100 Ml/d to Roding

-	Kennett PS to Gt Sampford	100%
-	Gt Bardfield PS to Stort & Roding	100%

The capital and operational costs for the above options are as follows:-

		Capital Cost £M	Operational Costs £M/annum
a)	100 Ml/d to Thame and 200 Ml/d to Stort	332	6.9
b)	100 Ml/d to Thame 100 Ml/d to Stort 100 Ml/d from Grafham *	316	6.5
c)	100 Ml/d to Thame 100 Ml/d to Stort 100 Ml/d to Roding (river)	348	6.9

* excluding treatment

7.0 ALTERNATIVE SCENARIOS FOR RESOURCE DEVELOPMENT

7.1 Background and Common Initial Elements of Scenarios

It is evident that no single scheme of those considered the most feasible and favourable options as described in Chapters 5 and 6, would alone be sufficient to meet the whole forecast public supply deficit to the planning horizon of 2021. This immediately points to the need for programmes of sequential development of resource options to meet the demand while maintaining standards of service and reliability at least at their present level, with the resources being developed just ahead of demand to provide a series of increments of output capacity as demands grow. This avoids the disadvantages of the "all the eggs in one basket" scenario, both in construction and in operation, reducing the need for very large "up-front" or premature expenditure inevitable with any single large scheme solution. This reduces the risk of commitment to works and expenditure that may in the event prove either unnecessary, or that could be deferred for some years.

We have accordingly put together and examined three alternative programmes of resource development or "scenarios", any of which would be capable in aggregate of providing the further output capacity forecast to be needed in Thames region in 2021. In formulating these scenarios we have taken the view that two of the development scheme options would be common initial elements for all three; thereafter the programme would differ. The two common resource options are:

(i) Thames-side Groundwater in the middle Thames catchment; and

(ii) London Basin Groundwater.

These schemes are so regarded because their favourable economics, limited adverse or even some positive environmental impacts and the relative speed with which they could be developed and brought into use to meet the most critical and pressing deficits in the region make a strong case for their inclusion early in the programme. Moreover their introduction would give time for the subsequent alternative courses, including reduction of demand by Demand Management and leakage reduction to be further assessed and for the favoured next scheme to be promoted and built. Assessment and implementation of these options by TWUL is well advanced and they are expected to be in operation by 1994.

All three resource development scenarios described in this chapter therefore have two common initial elements:

a) Thames-side Groundwater assessed to provide a total of 70 Ml/d from the middle reaches between Reading and Marlow to meet demands including peak demands in the Kennet-Reading and Slough-Wycombe-Aylesbury supply districts of TWUL. Effluent returns will augment river flows and support abstractions downstream including those of TWUL for London, and for other water undertakings in the lower catchment.

b) London Basin Groundwater is assumed to provide a resource value of 230 Ml/d over and above present abstraction when operated intermittently as described in Chapter 5. It has been assumed that 90 Ml/d of this new supply will be available by 1992, with the remainder by 1994. On present demand growth projections, this would meet average demands beyond that date only until about 1998/9 before a further tranche of resource capacity would be needed - see Figure 7.2. Meanwhile in the period until the London Basin scheme is fully implemented, there would be a theoretical deficit of resource capacity for the London supply area.

The three resource development scenarios have been devised to include all the short-listed options in at least one, in order to test yield and performance. They have regard to the practicalities of timing of promotion and construction of options as well as of perceived need for further resource capacity, and they take account of the most critical timing requirements rather than an average or aggregate situation for the whole region. Resource developments are therefore triggered by demands in the London area throughout the planning period.

7.2 Scenario 1 - Thames Region

This first scenario has been designed explicitly to examine the possibilities for meeting the full forecast public supply demand growth to 2021 by development of further water resources entirely within Thames Region, and therefore without recourse to transfers from other regions. The options included are shown schematically on Figure 7.1, while the results of the modelling are shown on Figure 7.2.

After the initial groundwater developments in the middle Thames and London Basin, assumed common to all scenarios as described in 7.1, this scenario would follow with an Abingdon/Drayton reservoir of 100,000 Ml/d usable storage as described in Chapter 5. This would provide 200 Ml/d additional yield for London, plus 66 Ml/d for upper Thames by direct supply. Other public supply intakes on the Thames between Day's Weir and the lower Thames reservoirs would also benefit incidentally. This would allow deficits other than those for TWUL, expected to arise from about 2006 onwards, to be satisfied, subject to increased abstraction being licensed when and where necessary.

Abingdon/Drayton reservoir would in theory be first needed to meet estimated demand growth in London, thus by about 1998, but it is not considered practicable to implement this option in only six years. We have assumed that the earliest the Abingdon reservoir could be completed and available for use is in 2001, allowing 10 years for planning, promotion, construction, filling and bringing into service. This is not a generous time-table for the scale of work involved but could just be achieved given timely decisions and effective promotion.

FIGURE 7.1

THAMES REGION - SCENARIO 1

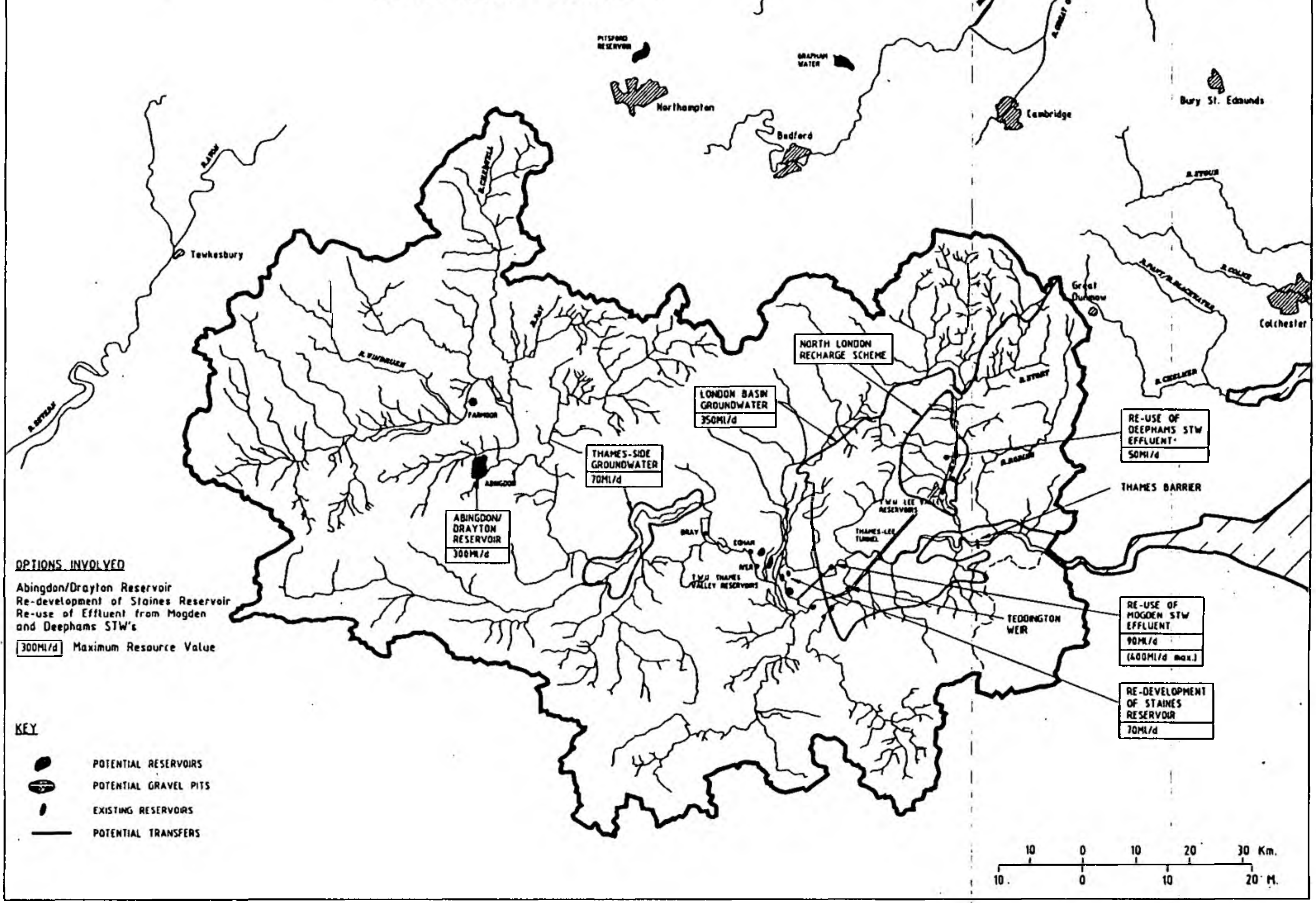
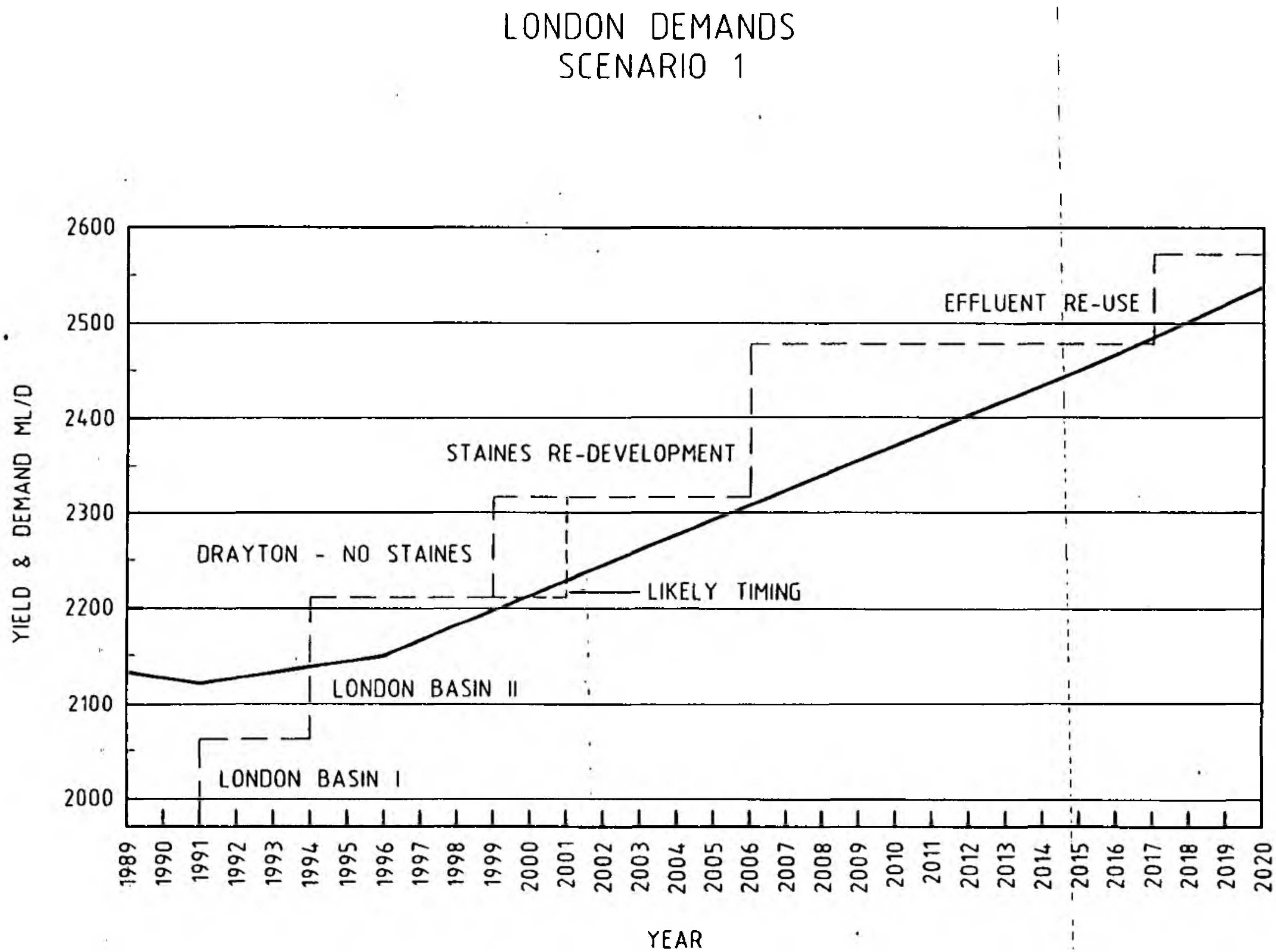


FIGURE 7.2



LONDON DEMANDS
SCENARIO 1
YIELD & DEMAND ML/D
2600
2500
2400
2300
2200
2100
2000
EFFLUENT RE-USE
STAINES RE-DEVELOPMENT
DRAYTON - NO STAINES
LIKELY TIMING
LONDON BASIN II
LONDON BASIN I
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
YEAR

The remaining Thames region developments included in the scenario are the redevelopment of existing storage at Staines reservoirs, and the re-use of effluents diverted from the tidal reaches.

A case can be made for either of these being the next development to be introduced when further resources are needed after full deployment of the new reservoir. This would occur in about 2012 based on the demand and deficit forecast provided for the study.

In this scenario the surplus capacity available for several years once Abingdon reservoir is fully commissioned will enable Staines Reservoirs to be drained down and taken out of service to allow reconstruction and enlargement to take place. Once the works are complete the overall resource value of the London system will be enhanced by an estimated further 70 Ml/d to meet demands until 2017.

From 2017 the first release of highly treated effluents diverted from the tidal reaches would be needed should dry weather river flows occur. As explained in Chapters 4 and 5, we have considered two effluent re-use options, from Mogden STW diverted to the Thames at Sunbury to provide replacement residual flow in dry periods, and from Deephams STW diverted into the Lee Valley resource system. For this scenario we have assumed that the Mogden scheme is implemented following the Staines reservoir enlargement, since Deephams cannot produce the effluent volumes required to meet demands.

Alternative development programmes could entail Deephams before Mogden and have either or both effluent re-use schemes before Staines reservoir enlargement. The latter might be a preferred solution if the Staines scheme proves on more detailed examination to be too difficult or even hazardous constructionally within the confines of the restricted site and if re-use of suitably treated effluents, especially for residual flow replacement can be shown to be environmentally and ecologically acceptable.

The nett present value of capital and operating costs at 5% discount rate of this scenario as programmed is £248 million, discounted back to 1991. On the assumptions used, this would be the cheapest of the development scenarios costed, being about 10% below the next lowest.

7.3 Scenario 2 - Thames Region and Severn Transfers

This scenario as originally formulated, differs from the previous one after the Abingdon reservoir output capacity is fully taken up, that is, from about 2012. Instead of enlargement of Staines reservoir and effluent re-use, this scenario provides for Severn-Thames transfers being available from that date (see Figure 7.3). Based on a transfer rate of 400 Ml/d, resources would be sufficient to meet forecast demands to the planning horizon of 2021, as shown on Figure 7.4. Transfers could either be taken directly to the reservoir by pipeline or could be released into the river at Buscot for abstraction at the Culham intake.

Apart from meeting abstraction demands, this transfer option would also enhance river flows in the upper and middle reaches of the Thames during periods of transfer and augmentation. For the upper Thames this could include times when abstraction was taking place from the river at Culham to refill Abingdon reservoir. In comparison with Scenario 1 this scenario would therefore further increase and regulate flows in the Thames, providing significant general benefit to the river while allowing greater benefit for all abstractors. At the same time the transfers inevitably give rise to water quality concerns such as compatibility and consistency of chemical, bacteriological and viral content, and impact on both in-river conditions and abstracted uses. We believe that with adequate measures for dilution, blending, settlement, and exclusion from transfers of more seriously polluted or unsuitable water and with treatment, these quality issues could be satisfactorily addressed.

From an environmental standpoint, discharge of transfers to the Abingdon/Drayton reservoir is preferred to release to the Thames at Buscot.

FIGURE 7.3

THAMES REGION - SEVERN TRANSFER - SCENARIO 2

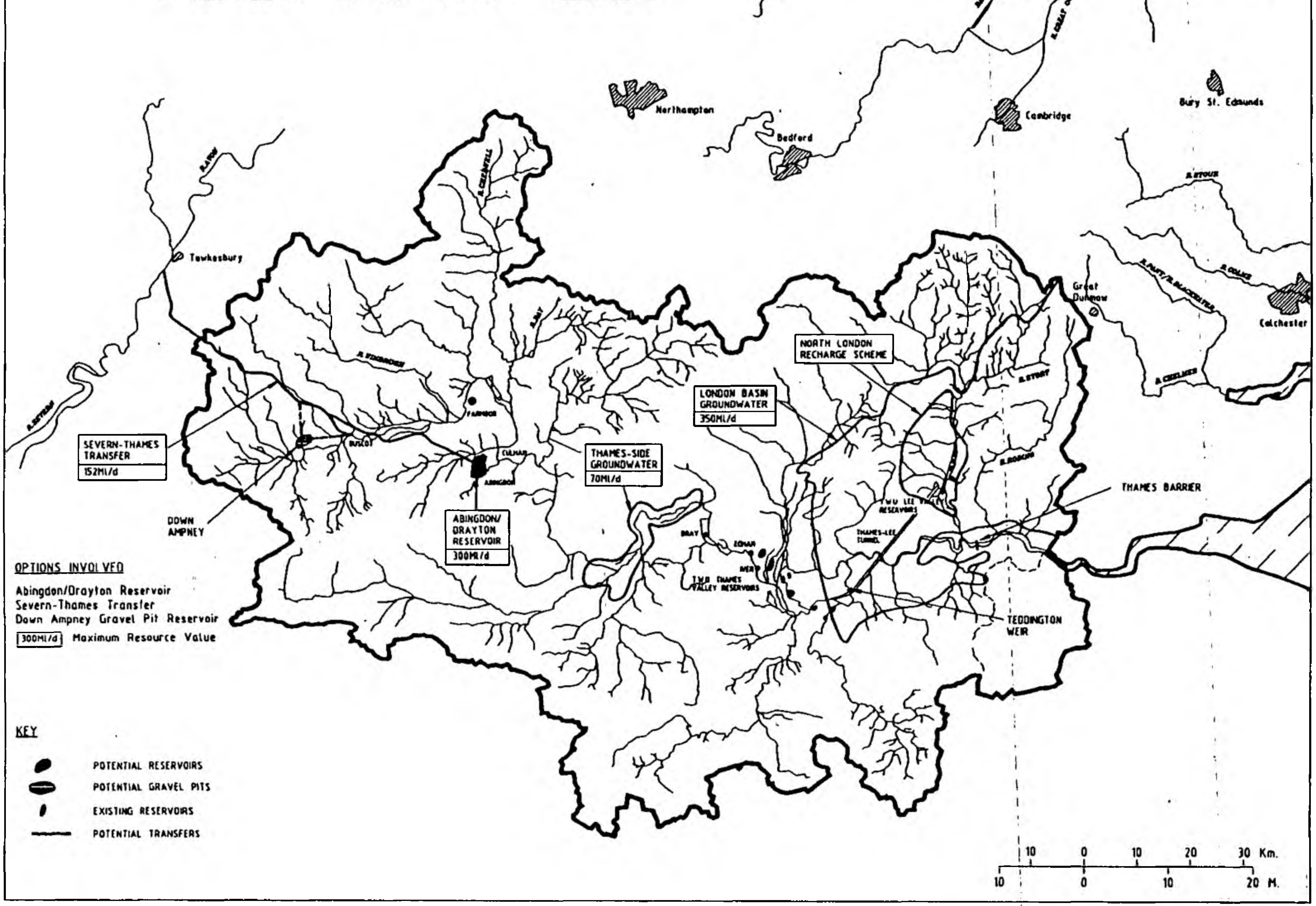
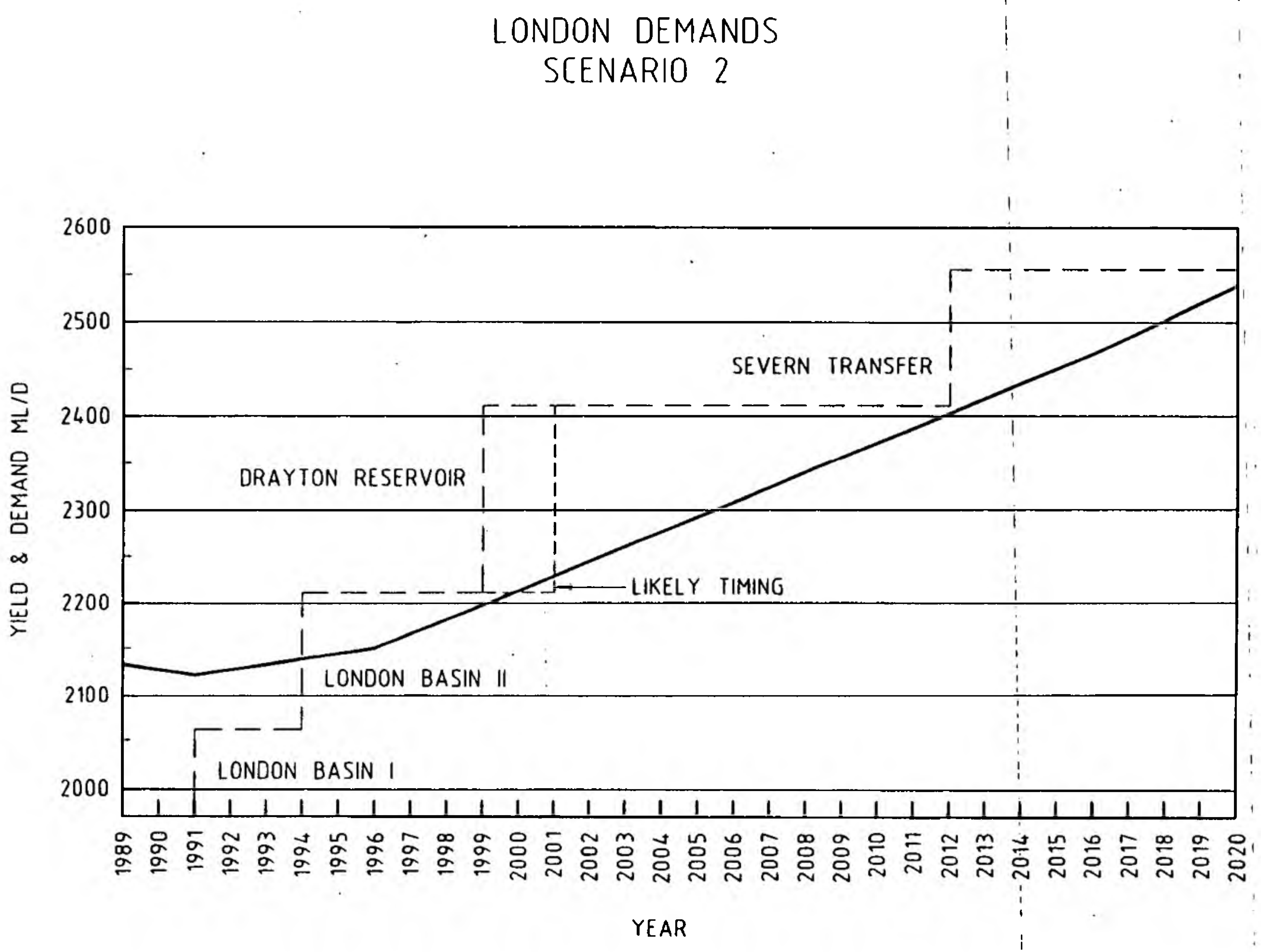


FIGURE 7.4


LONDON DEMANDS
SCENARIO 2
YIELD & DEMAND ML/D
2600
2500
2400
2300
2200
2100
2000
SEVERN TRANSFER
DRAYTON RESERVOIR
LIKELY TIMING
LONDON BASIN II
LONDON BASIN I
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
YEAR

A sub-option of this scenario would involve the Severn-Thames transfers preceding the introduction of Abingdon reservoir (see Figures 7.5). Because transfers from the Severn in the options examined are not supported by dedicated storage within the donor catchment, it means that they rely on storage in the Thames catchment to provide output to supply through critical dry periods. In this case the existing lower Thames reservoirs would provide this storage and the Severn transfers would enhance their yield by some 135 Ml/d. This would meet the demands of London, and indirectly of the rest of the region, until about 2008, by which time Abingdon reservoir would be needed.

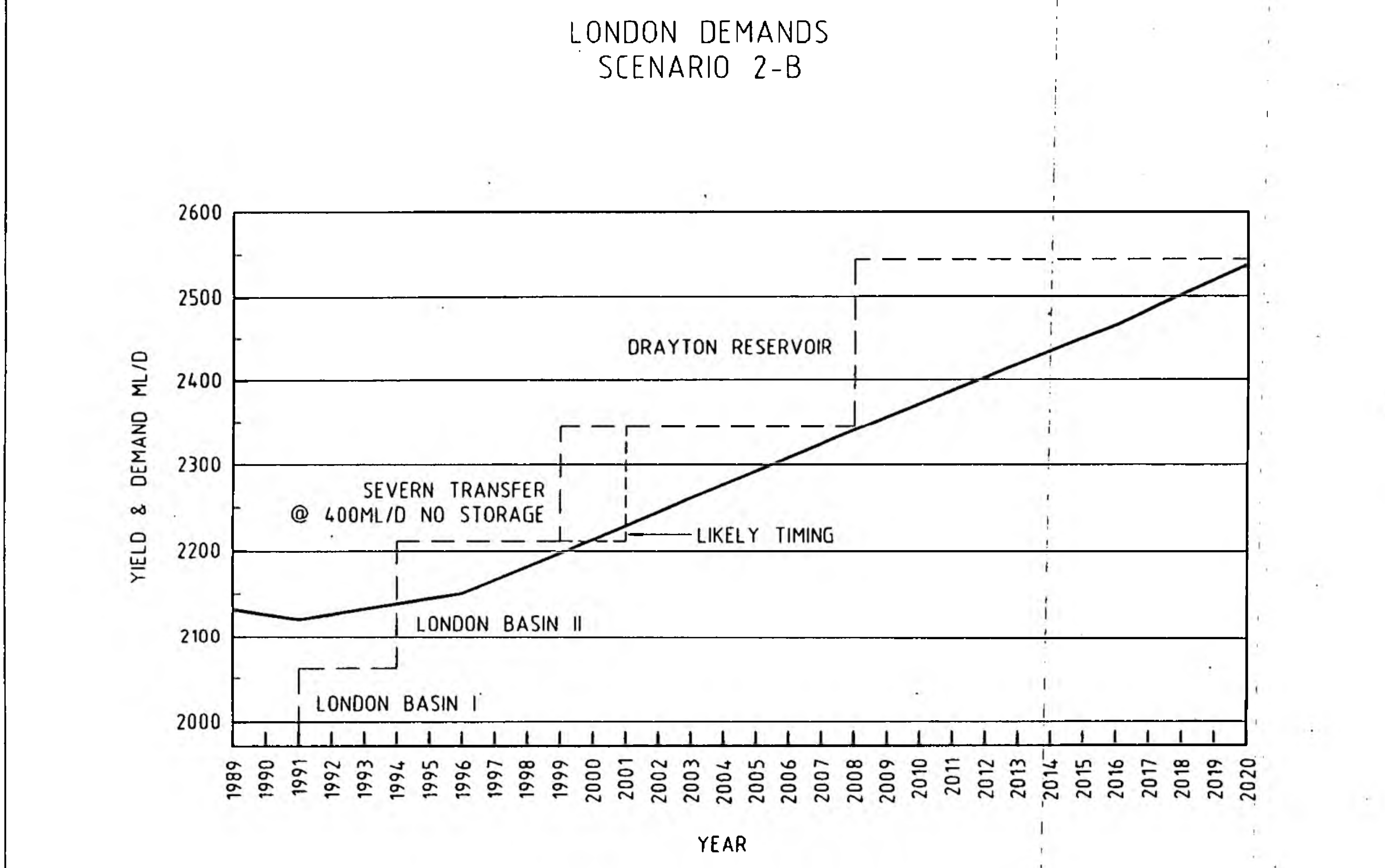
The second of the above alternatives, ie with Severn transfers preceding Abingdon reservoir, would be the cheaper by about £29 million or 10%, but with a net present value of £275 million it is still some £27 million or 10% more than the internal Thames regional solution in Scenario 1.

7.4 Scenario 3 - Severn and Anglian Transfers

This scenario has been formulated to illustrate a possible resource development programme without any further Thames region schemes after the initial Groundwater proposals described in 7.1. Thus it excludes Abingdon/Drayton reservoir and subsequent schemes of Scenario 1, depending instead on transfers from both the Severn region and from Anglian region (ultimately supported by abstractions from the lower Trent), as shown on Figure 7.6. The scenario examined assumes that Severn transfers of up to 400 Ml/d would be introduced first, in 2001. This is estimated to provide an increment of yield of 135 Ml/d to the Thames resource system, meeting needs until 2008 before further resources would be required (see Figure 7.7).

Transfers of 200 Ml/d linked to 25,000 Ml storage in gravel pits in the upper Thames could provide an alternative first stage development, as shown on Figure 7.8, but it would probably not be possible to develop the storage within the limited time available.

FIGURE 7.5



LONDON DEMANDS
SCENARIO 2-B
2600
2500
2400
2300
2200
2100
2000
YIELD & DEMAND ML/D
DRAYTON RESERVOIR
SEVERN TRANSFER
@ 400ML/D NO STORAGE
LIKELY TIMING
LONDON BASIN II
LONDON BASIN I
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
YEAR

FIGURE 7.6

SEVERN-ANGLIAN TRANSFERS - SCENARIO 3

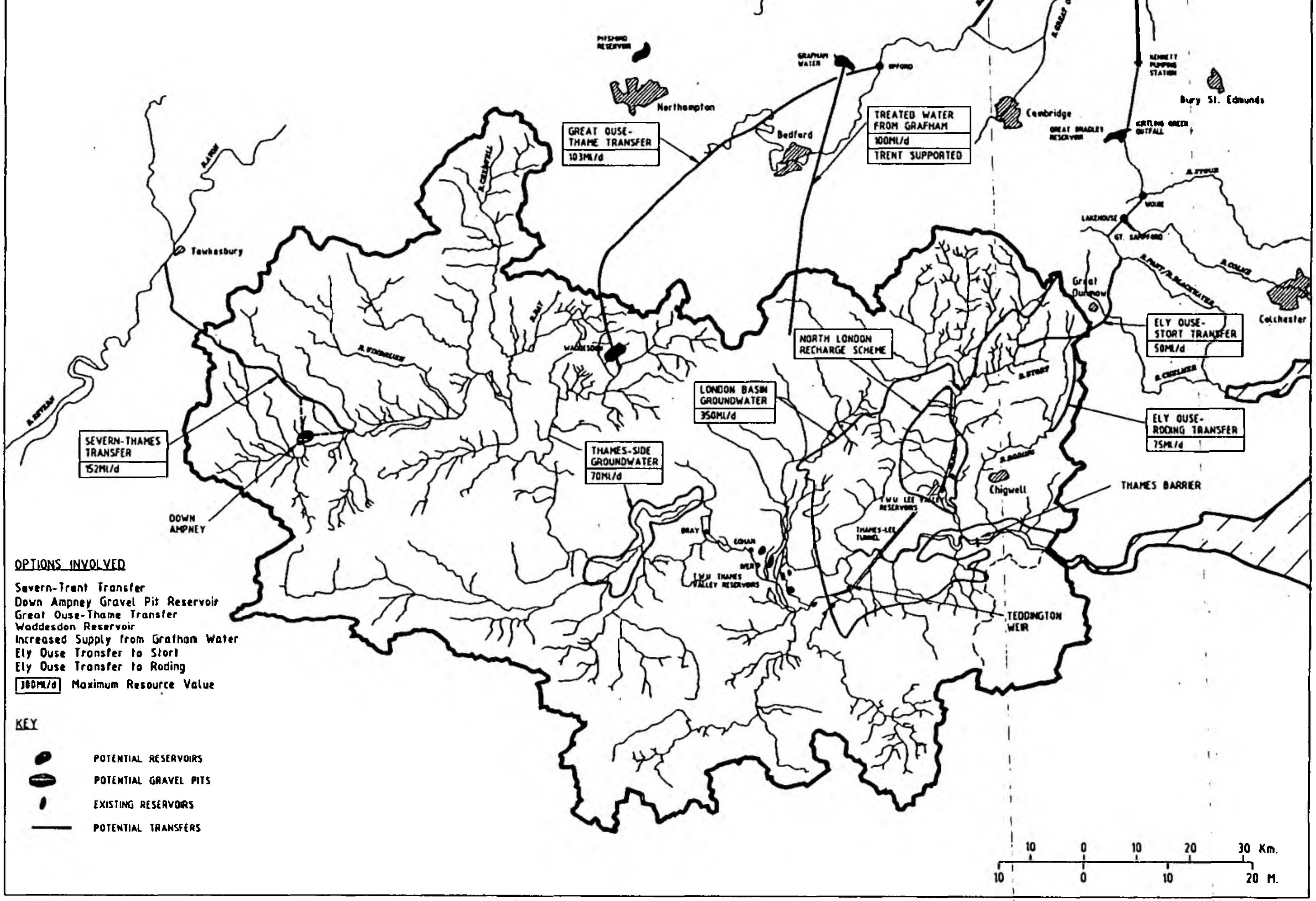


FIGURE 7.7

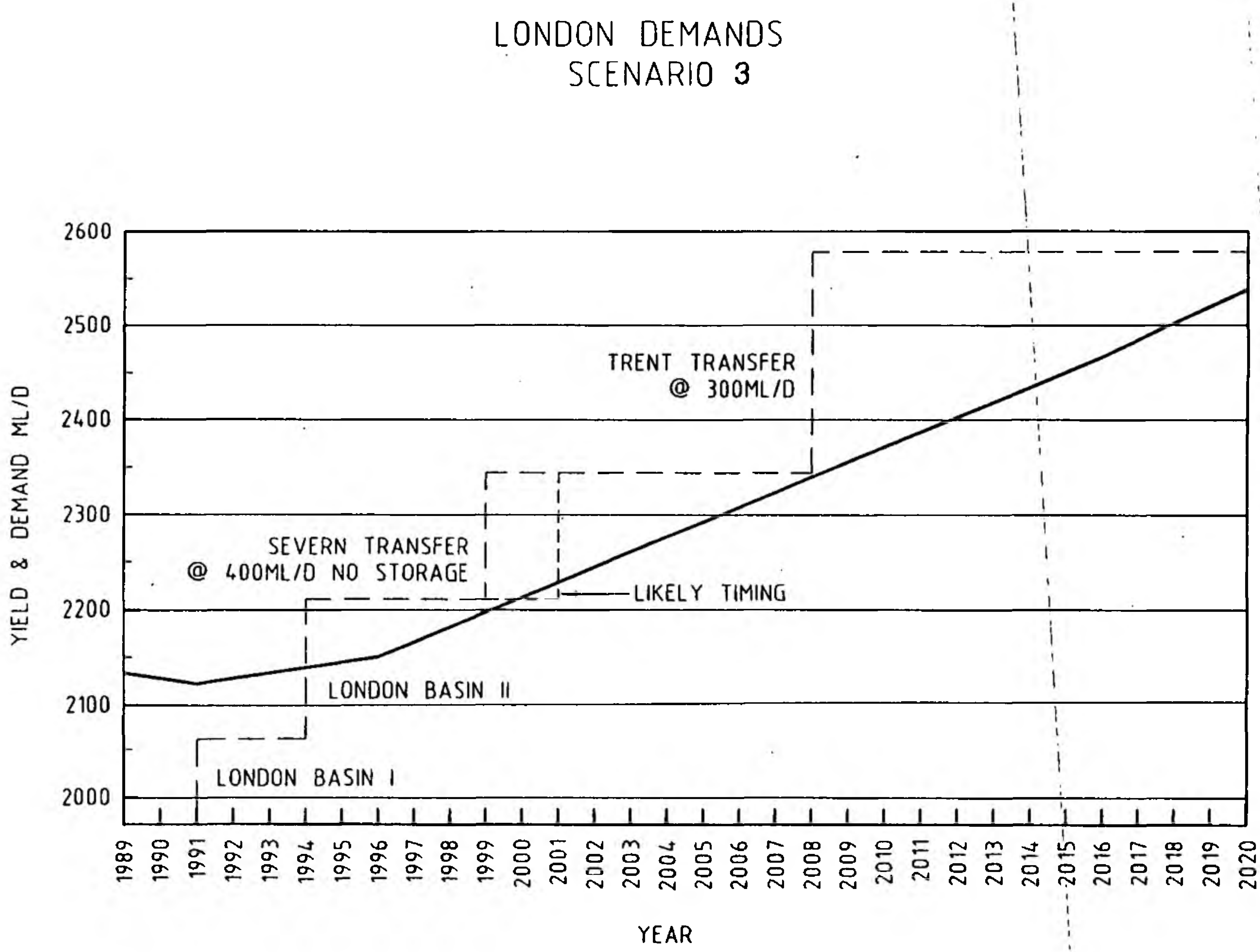
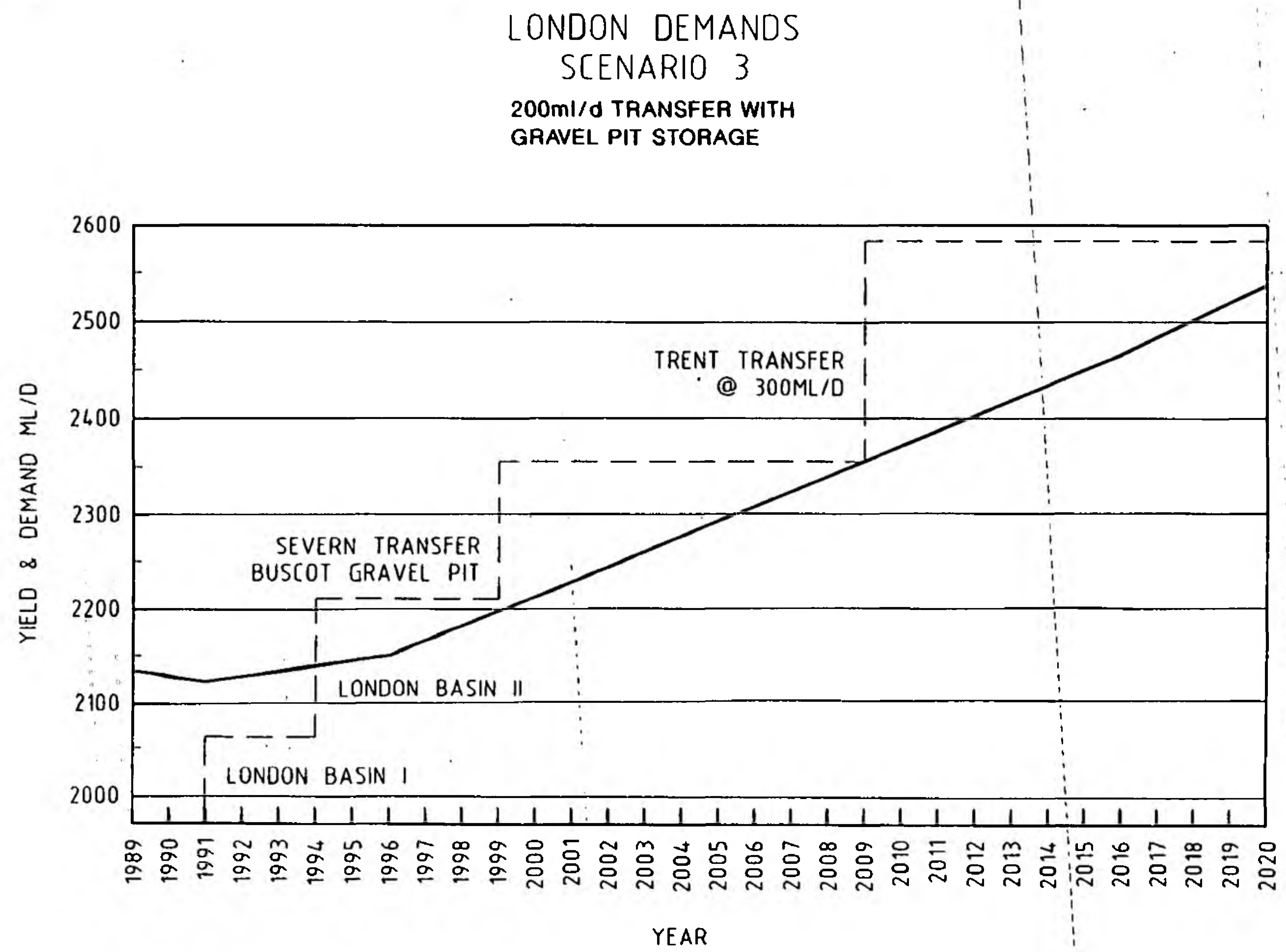

LONDON DEMANDS
SCENARIO 3
YIELD & DEMAND ML/D
2600
2500
2400
2300
2200
2100
2000
TRENT TRANSFER
@ 300ML/D
SEVERN TRANSFER
@ 400ML/D NO STORAGE
LIKELY TIMING
LONDON BASIN II
LONDON BASIN I
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
YEAR

FIGURE 7.8



LONDON DEMANDS
SCENARIO 3
200ml/d TRANSFER WITH
GRAVEL PIT STORAGE
YIELD & DEMAND ML/D
2600
2500
2400
2300
2200
2100
2000
TRENT TRANSFER
@ 300ML/D
SEVERN TRANSFER
BUSCOT GRAVEL PIT
LONDON BASIN II
LONDON BASIN I
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
YEAR

Transfers from Anglian region would be introduced in 2008, with the present 90 Ml/d bulk supply from TWUL to Essex WC being replaced by Anglian sources using 100 Ml/d of the transfer total. The other Anglian transfers are assumed to comprise a maximum rate of transfer of 100 Ml/d to the upper Thame with balancing storage at Waddesdon, west of Aylesbury, and a further 100 Ml/d maximum transfer to the Stort tributary of the River Lee.

Other variants of this scenario include further treated water supplies from Grafham reservoir to Three Valleys WC, and transfer to the river Roding. All variants have allowed for the same total transferred quantities of 300 Ml/d.

The lowest cost variant of Scenario 3, comprises the Severn transfer and the Thame, Stort, and Grafham transfers from Anglian region, and has a total present value of capital and running costs of £301 million. This compares with £248 million for Scenario 1 and £275 million for the least cost version of Scenario 2. It is thus 21% more expensive than Scenario 1 and 10% more than Scenario 2. It is hard to argue that there are compensating advantages and benefits that would justify this significant additional cost in comparison with the other scenarios.

The scenarios presented do not purport to identify every possible variant of order of development, staging, or size and output of schemes. However it is believed that they do identify and realistically assessed the principal feasible options and their implications sufficiently clearly to lead to a well founded choice following further investigation and assessment of factors referred to in Chapter 8.

7.5 Effects on Non-London Deficits

Non-London Resource Value

In the previous sections the scenarios have only been directly concerned with the levels of service in the London area and hence the resource value of the various scenarios to London of augmentation schemes. As discussed there will also be indirect benefit to other Thames abstractors such as Mid-Southern WC, Three Valleys WC and North Surrey WC. There would appear to be no useful benefit to North Surrey as demands are satisfied through to 2021 with the existing source/licences.

The present Bray source will satisfy demands for Mid-Southern WC until at least 2007. The average deficit in the year 2021 could be met by an increased abstraction at Bray without seriously affecting the levels of service in London, as the effluent from Mid-Southern WC is returned to the Thames via the river Blackwater/Loddon.

Similarly the present river Iver source will satisfy demands in the Three Valleys WC area until about 2006. The average deficit of 34 Ml/d in the year 2021 could be met by an increased abstraction at Iver with only a small effect on the levels of service in London. This is due to the fact that the majority of effluent from Three Valleys WC is returned to the freshwater Thames (some is lost to the Tideway).

In both these cases the increased abstraction would have to be obtained with a revision of the existing licences. Theoretically, the operation of an augmentation scheme could provide a significantly higher resource value through increased abstraction and recycling upstream of London. Abstractions at Bray and Iver could be substantially increased with no consequent impact on the levels of service in London.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Demands and Deficits

Public water supply daily average demands are estimated to rise from the present 4031 Ml/d to 5083 Ml/d in 2021, allowing for very modest improvements in control of unaccounted-for water.

More ambitious leakage control targets set by the water undertakings, if achieved, would reduce the 2021 figure to 4641 Ml/d.

Seasonal summer (3 months) peak demands are proposed as the basis of resources development planning, particularly as future supplies will predominantly be derived from surface water. Seasonal demands are expected to rise from 4210 Ml/d in 1991 to 5314 Ml/d by 2021, or to 4641 Ml/d with greater leakage control.

Present public water supply yields are 4224 Ml/d, rising to 4239 Ml/d by 2001 due to phased increases of existing licences, and allowing for reduction of yield in the river Ver, Misbourne, Pang and Darent catchments for environmental reasons. There is a prevailing deficit of 155 Ml/d in the London area of TWUL.

Demand deficits in the region in 2021 amount to 852 Ml/d and 1079 Ml/d for average and seasonal daily demands respectively; the figures decline to 433 Ml/d and 627 Ml/d with greater leakage control. The bulk of the deficits occur in the London area, and these are the trigger for strategic resource developments throughout the planning period.

Non-potable water supply licensed abstractions, excluding cooling water for power generation in London which is taken from the tidal reaches of the Thames, amount to 1190 Ml/d. There is a considerable difference of 437

Ml/d between licensed abstraction and actual abstraction (excluding power generation cooling) which appears to be significant in terms of the forecast deficit for public water supplies in 2021.

Growth in non-public water supply demand is low. Licence applications totalled about 21 Ml/d for each of the last two years. The increase in demand within this sector appears unlikely to grow sufficiently to have a noticeable effect on the resource/demand balance.

The overall deficit forecasts suggest that planning at present for an aggregate of new resources for public supplies with a resource value of up to 1000 Ml/d would be of the right order, but limiting the initial storage of development planning and scheme promotion to about 500 Ml/d regionally. This will enable phasing of source development to take account of enhancement or reduction in the planning demand target over the next 10 - 15 years as demand forecasts for 2011 and 2021 are refined.

The justification and trigger for water resource development has traditionally been growth of demand, ongoing and forecast, even if other uses and justification have been advanced at the planning and promotion stage. However it is now evident that there are other reasons why resource development may be required, the principal of these being:-

- climate change giving rise to greater variations of weather and hence the need for more resources in terms of storage and inter-regional links to balance wider variations in respect of both time and place and to provide for a greater level of uncertainty about future climatic effects.

- greater public expectations concerning reliability of supplies.

- the need to ensure that water resources are developed and operated to benefit rather than derogate from the environment. This has several implications, notably much more constrained use or even abandonment of some existing sources, mainly groundwater, that may have to be replaced by new sources. Indeed initial provision for this is made in this study, with assumed replacement of sources totalling 77 Ml/d to alleviate low flows. Other sources may follow when new schemes provide the capacity to allow their substitution.

All these resource driven, as opposed to demand driven, reasons for resource enhancement, have potentially large implications for existing source yields, very likely giving rise to a need for downward reappraisal.

In summary therefore, although the given estimates of future demand growth, and hence deficits, requiring new resource development may be high and difficult to justify, this is at least partly countered by the need for resources to be developed for the foregoing reasons of possible climate change, greater hydrological uncertainty, increased expectations of reliability and greater environmental concerns.

While the study has examined in outline detail the potential strategic development options to meet the forecast deficits, we have also indicated the significant role that could be played by improvements in demand forecasting, and by demand management measures.

8.2 Demand Forecasting and Demand Management

The demand forecasts produced by the water undertakings are based on a number of assumptions that require review and substantiation. Among these are a 38% increase in domestic demand by 2011, predominantly from per capita growth rather than population increase, and a 35% growth in unmetered commercial demands. The reasoning behind these increases needs to be carefully examined for each undertaking to establish a common basis for forecasting demands.

There is no explicit provision in the demand forecasts for the possible impact of demand management generally, or domestic metering in particular. At present, there are only alternative forecasts to allow for meeting additional targets for reduced leakage from mains. It is proposed that other demand forecasts should be produced which allow for the effect of the introduction of demand management, including domestic metering, in Thames region over the planning period. These would provide the basis for a lower bound to the range of future demand growth assumptions and, when the management measures were costed, would allow comparison with the strategic resource development options that would otherwise be necessary.

In making comparison of scenarios and scheme options, the significant potential impact of reduced leakage, and demands moderated by possible future tariff changes, especially the likelihood of selective domestic metering, should be at the forefront of future assessments and analysis. Full attainment of the more ambitious leakage targets set by the undertakers could alone postpone the need for a major new resource such as Abingdon or Severn transfers by as much as 15 years. Even if such large leakage reductions may prove unattainable, the combination of lesser leakage reductions with moderated demand growth stemming from selected domestic metering would have a similar effect.

8.3 Potential Resource Development Options

From the strategic resource development options examined, those with promising potential to meet present and future deficits within Thames Region are:-

a) Thames-side groundwater in the Reading to Marlow area.

b) London Basin groundwater in the confined central area, operated as a single resource.

c) Surface storage, at Abingdon/Drayton, based on Thames' flows, with direct supply to upper Thames area, and regulation of the river Thames for the TWUL London reservoirs and the benefit of other abstractors.

d) Redevelopment of the TWUL Staines reservoirs.

e) Re-use of highly tertiary treated sewage effluent from Mogden STW (and perhaps Deephams STW) to discharge to the river Thames above Teddington weir, thereby releasing river flows for abstraction in the lower reaches.

f) Transfers from the river Severn, with or without associated storage in the upper Thames, and discharging to the river Thames at Buscot, or to Abingdon/Drayton reservoir if implemented, with regulation of the middle and lower Thames for the benefit of all abstractors.

g) Transfers from the Anglian Region based on Trent supported river-to-river transfers with potential for release into Thames Region via the river Thame (with storage) thereby regulating the river Thames, by direct supply of additional treated water from Grafham Water, release via the river Stort, or by direct pipeline to Essex Water Company at Chigwell; transfer via the river Roding is not considered possible without channelisation. The Thame sub-option could benefit all abstractors on the lower Thames, while the other sub-option would serve TWUL and Three Valleys WC.

These options are compared and contrasted in the next section.

8.4 Comparison of Options

The anticipated environmental effects of the construction and operation phases of each resource development option and sub-option are set out in Table 8.1.

Scores for the matrix have been arrived at after the analysis of each option and sub-option as presented in Appendix 5. It should be stressed that the matrix presents an aid to comparative analysis of the options rather than an absolute 'score' for each. In addition the impacts which are summarised into plus (benefits) and minus (disbenefits) scores are impacts on the environment, starting from a baseline position. They are not impacts assessed relative to other options. This relates particularly to the sub-options and means that where one sub-option scores more favourably than another, the benefits achieved by not pursuing the damaging option are not input to the scoring process.

As stated, the scores presented in the matrix for each environmental component are a broad summary of impacts for the purposes of comparison of options (Table 8.2) and Scenarios (Table 8.3). The scores have been further summarised to comments for the construction and operation stages, in terms of low, moderate and high impacts, both positive and negative.

The groundwater options, redevelopment of Staines reservoir, increased use of Grafham Water and re-use of effluent have very limited adverse impacts, while control of groundwater levels by the London Basin option has a very beneficial effect on the human environment in London. Inter-regional transfers have the greatest adverse impacts because of the scale of works involved and the uncertainties as to the effects on the aquatic biology of the receiving rivers. This is demonstrated in Table 8.2 where the various scores for environmental impacts in the construction and the operational phases have been combined. Anticipated adverse effects are greater for the Anglian transfer options than the Severn option due to the difference in size of the receiving river and thus the proportionally greater impact of the released water.

TABLE 8.1 ENVIRONMENTAL COMPARISON OF OPTIONS

Option/Sub-option	Phase	Planning/ Development		Agriculture/ Drainage		Landscape/ Visual Impact		Recreational Amenity		Archaeology/ History		Terrest Ecology		Aquatic Ecology		Fisheries	
		Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben
a) Thames-side Groundwater	Con	0		0		-1		-1		0		0		0		0	
	Op	0		0		0		0		0		0		0		0	
b) London Basin	Con	0		0		0		0		0		0		0		0	
	Op	0	+2	0		0		0		0		0		0		0	
c) Abingdon/Drayton Reservoir	Con	-2		-2		-3		-2		-2		-2		-1		0	
	Op	-1		-2		-1	+1	-1	+3	0	+2	0	+2	-1	+1	-1	
d) Redevelopment of Staines Reservoir	Con	-2		0		-2		-2		-1		-1		-1		0	
	Op	-2		0		-3		0		0		0		0		0	
e) Re-use of Effluent	Con	0		0		0		0		0		0		0		0	
	Op	0		0		0		-1		0		0		-1		0	
f) Severn-Trent Transfer																	
i) To Abingdon/Drayton reservoir	Con	-2		-3		-3		-1		-1		-1		0		0	
	Op	-1		-1		-2		-1		0		0		-2		-2	
ii) To Buscot - 400 Ml/d	Con	-2		-3		-3		-1		-1		-1		0		0	
	Op	-1		-1		-2		-1		0		0		-1		-1	
g) Anglian Region Transfer																	
i) Thame transfer	Con	-3		-3		-3		-2		-1		-1		0		0	
	Op	-1		-1		-2		0		0		0		-1		-1	
ii) Stort transfer - 200 Ml/d	Con	-2		-2		-2		0		-1		-1		0		0	
	Op	0		0		0		0		0		0		-3		-2	
- 100 Ml/d	Con	-2		-2		-2		0		-1		-1		0		0	
	Op	0		0		0		0		0		0		-2		-1	
iii) Roding Transfer	Con	0		-2		-2		0		-1		-1		0		0	
	Op	0		0		0		0		0		0		-3		-3	
iv) Increase in Grafham water use	Con	0		0		0		-1		0		0		0		0	
	Op	0		0		0		-1		0		0		0		0	

Option/Sub-option	Phase	Planning/ Development		Agriculture/ Drainage		Landscape/ Visual Impact		Recreational Amenity		Archaeology/ History		Terrest Ecology		Aquatic Ecology		Fisheries	
		Dis	Ben	Dis	Ben	Dis	Ben	Dis.	Ben	Dis.	Ben	Dis.	Ben	Dis.	Ben	Dis	Ben
h) Storage with Transfers																	
i) Waddesdon Reservoir	Con	-2		-2		-2		-1		-1		-2		0		0	
	Op	0		-1		-1	+1	0	+1	0		0	+1	0		0	
ii) Down Ampney Reservoir	Con	-2		0		0		0		0		0		0		0	
	Op	-2		-2		0		0		0		0		0		0	
iii) Stanton-Harcourt Reservoir	Con	-2		0		0		0		0		0		0		0	
	Op	-2		0		0	+1	0	+1	0		0		0		0	
iv) Cassington-Yarnton Reservoir	Con	-2		0		0		0		0		0		0		0	
	Op	-2		0		0	+1	0	+1	0		0		0		0	

TABLE 8.2 COMPARISON OF STRATEGIC RESOURCE DEVELOPMENT OPTIONS

Option/Sub-option	Max Yield Ml/d	Additional Resource Value Ml/d	Capital Cost	NPV **	AIC x** Water £/m³	Water Quality	Environ. - Const. + Disbenefits	Environ. -Operat. + Disb.	Environ. -Operat. + Ben	Comment
a) Thames-side Groundwater	70	70	N/A	N/A	N/A	0	Low	0		In progress
b) London Basin Groundwater	-	231	N/A	N/A	N/A	0	0	0	Low	In progress
c) Abingdon/Drayton Reservoir*	600	300	327	223	0.21	-2	High	Mod	Mod	In study
d) Redevelopment of Staines Reservoir	-	70	20	15	0.06	0	-Mod	Mod	0	In study
e) Re-use of Effluent	90	68	39	32	0.13	-1	0	Low	0	
f) Severn-Thames Transfer *										
i) to Abingdon/Drayton Reservoir	400	152	188	146	0.27	-1	High	Mod	0	
ii) To Down Ampney	200	151	118	95	0.18		High	Mod	0	
iii) To Buscot-400 Ml/d	400	135	155	118.5	0.25	-2	High	Mod	0	
iv) To Buscot - 200 Ml/d	200	85	83	68	0.23	-	High	Mod	Low	
g) Anglian Region Transfer *										
Thame/Stort	300	242	332	296	0.35					
Grafham/Stort	300	242	316	279	0.33					
Thame/Stort/Roding	300	242	348	355	0.36					
i) Thame transfer with storage *	100	103	N/A	N/A	N/A	-2	Mod	Mod	0	
ii) Stort transfer (no storage) - 200 Ml/d	200	N/A	N/A	N/A	N/A	-2	Mod	Low	0	Not acceptable without channelisation
- 100 Ml/d	100	50	N/A	N/A	N/A	-2	Mod	Low	0	

Option/Sub-option			Max Yield Ml/d	Additional Resource Value M/ld	Capital Cost	NPV **	AIC x** Water £/m³	Water Quality	Environ. - Const, + Disbenefits	Environ. -Operat. + Disb.	Environ. -Operat. + Ben	Comment
	iii)	Roding Transfer (no storage)			N/A	N/A	N/A	-2	Mod	Mod	0	Not acceptable - use pipeline
	iv)	Increase in Grafham water use	100	100	N/A	N/A	N/A	-1	Low	Low	Low	
b)	Storage with Transfers											
	i)	Waddesdon Reservoir		incl	18	N/A	N/A	-2	High	Low	Low	Pre.. studies
	ii)	Down Ampney Reservoir - 200 Ml/d		incl	13	N/A	N/A	-2	Low	Low	Low	Preferred option
	iii)	Stanton Harcourt Reservoir		-	-	-	-	-2	Low	Low	Low	
	iv)	Cassington-Yarnton Reservoir		-	-	-	-	-2	Low	Low	Low	

* Regulation of river Thames produces significant indirect yields for areas other than London

** Discounted at 5% per annum back to 1991 assuming all scenarios came 'on-stream' is 2001 and operating until 2021.

x** AIC - Average Incremental Cost of water based on satisfying London and other deficits increasing up to 2021.

\+ Where 1-4 = Low, 5-9 = Moderate, 10 and above = High

TABLE 8.3 COMPARISON OF SCENARIOS

Scenario	Options	Capital Cost £m	Engineering Cost £m	Total Cost £m	NPV ** £m	AIC x** Water £/m³	Water Quality	Environment		
								Constr. +	Operat. +	
								Disbenefit	Disb.	Ben
1	Drayton Res. - Staines Res. - Effluent	367	25	392	248	0.26	-3	Low	Low	Mod
2	Drayton Res. - Severn (Drayton)	470	30	500	294	0.31	-3	Mod	Low	Mod
2A	Drayton Res. - Severn (Buscot)	494	33	527	304	0.32	-4	Mod	Low	Mod
2B	Severn (Buscot) - Drayton Res.	470	29	499	275	0.29	-4	Mod	Low	Mod
3	Severn (Buscot) - Anglian (Thame, Stort)	476	34	510	311	0.32	-8	High	Mod	Low
3A	Severn (Buscot) - Anglian (Thame, Stort, Grafham) - 100 Ml/d to Stort	456	34	490	301	0.32	-8	High	High	Mod
3B	Severn (Buscot) - Anglia (Thame, Stort, Roding) - 100 Ml/d to Stort	486	37	523	319	0.34	-10	High	High	Low

* Includes regenerating of capital cost of M & E plant every 15 years

** Discounted at 5% per annum back to 1991 assuming all scenarios come "on-stream" in 2001 and operating until 2031

x** AIC - Average Incremental Cost of water based on satisfying London and other deficits increasing up to 2021 then constant

\+ Where 20-25 = Low, 26-30 = Moderate, 31 and above = High

○ Where Disbenefits 1-5 = Low, 5-10 = Moderate, 11 and above = High

Thames Region development options, that is Abingdon/Drayton reservoir, redevelopment of Staines reservoir and re-use of effluent presently discharged to the tideway, all have substantially cheaper unit costs than the inter-regional options.

In addition to the direct yield figures given in Table 8.2, those options that involve regulation of the Thames, that is the Abingdon/Drayton reservoir, Severn transfer and Thame transfer options, can all provide significant indirect yields for other intakes on the Thames, with abstraction/effluent return occurring down the river until the targeted TWUL intake is reached.

The extent to which these options should be viewed as general regional resource developments meeting all demands or as specific to the demands of certain undertakings should be addressed by the NRA.

8.5 Comparison of Development Scenarios

A comparison of the three development scenarios and variants on cost, water quality and environmental grounds is presented in Table 8.3, as discussed previously, all of the scenarios have Thames-side Groundwater and London Basin Groundwater as their initial elements.

As might be expected from the discussion on options, the Thames Region Scenario 1 is considerably cheaper, and has less potential adverse impact on water quality and the environment.

The other scenarios are comparable in cost, but the Severn and Anglian Transfers, Scenario 3 has considerably greater potential for adverse impact on water quality and the environment. This is primarily a function of the larger scale of works, and the greater number of smaller sized receiving rivers.

Water quality and environmental scores however, only reflect the comparative potential for adverse impact, and careful planning, design, construction and operation measures will largely mitigate these effects, particulary at the operational stage.

8.6 Preferred Development Options/Scenario

The significant additional cost of the Severn and Anglian Transfers, Scenario 3 without evident attendant benefits and advantages suggests that the final weighing of options should rest between Scenario 1, the lowest cost internal Thames regional solution, with its probable reliance on effluent re-use and heavy abstraction of river flows in the middle to upper reaches and Scenario 2 with one major regional transfer from the Severn to augment the region's own heavily used water resources, but with quality problems associated with the transfer to overcome, and at a cost some 10% more than Scenario 1. It does not seem desirable to continue promoting purely regional resource developments that further increase the already very considerable exploitation of catchment resources. Following optional development of the groundwater potential there would appear to be considerable benefit in developing major regulating surface water storage within the Thames catchment and introducing regulating transfers from the River Severn. These options can be combined very effectively to regulate the flows in the Thames to meet needs at all major demand centres within the Thames region to the planning horizon of 2021.

Either option could be put in place by 2001, to meet forecast demands to at least 2008. The implementation of the Severn transfer first would defer construction of Drayton for at least 7 years, by which time demand forecasts trends should be better defined.

This deferment would keep storage options open and if at that time regulatory storage requirements were modest, it might be preferable to implement a reservoir in the Down Ampney area using gravel pit storage.

We therefore recommend that the Abingdon/Drayton reservoir, Severn-Thames transfer and Down Ampney gravel pit storage options should be pursued in further studies, with a view to some combination forming the preferred development scenario following full implementation of the groundwater schemes. We further recommend that these options should be explored on the basis of regulation of the river Thames for the benefit of all abstractors in the region.

Elements of the Anglian regional development scheme could prove cheap and useful additions to the final development scenario comprising:

a) increase in treated water from Grafham Water to Three Valleys Water Company,

b) additional supplies from Anglian region to Essex Water Company (Great Bradley or other), allowing release of 91 Ml/d supply back to TWUL.

c) treated water from the possible Great Bradley reservoir, based on Ely Ouse resources, with Trent water if needed,

None of these elements involve river to river transfer within Thames region. Only treated water transfers are involved and therefore water quality and environmental impacts will be minimal. Further investigations of these options will be possible when the initial phase of the Anglian Region NRA studies is completed at the end of March 1992.

None of the options discussed above can be realistically implemented before 2001, and therefore, as discussed in Chapter 7, there will be a theoretical deficit in the London area from 1999-2001. The only options that could be implemented on a timescale consistent with addressing this deficit are:

a) re-use of effluent from Deephams STW,

b) cessation of TWUL bulk supply to Essex WC at Chigwell,

c) temporary increase in abstraction from the London Basin.

Use of Deephams effluent would depend on gaining public acceptance of effluent re-use, in the manner proposed. Increased groundwater abstraction on a temporary basis would appear the easiest solution.

8.7 Recommended Additional Work and Studies

8.7.1 Demand Forecast and Management

Further demand forecasts need to be critically reviewed and assessed in-depth in terms of the underlying assumptions in order to ensure a common approach by all water undertakings and to produce realistic demand forecasts based on reasonable extrapolation of previous trends and population/economic projections.

There is also a need for a detailed examination of the impact on demand and the costs of introducing demand management measures, including metering of domestic water supplies and tariff charges.

8.7.2 London Basin Groundwater

The optimal management of this resource should be further refined by integrated use of the Water Resources Model and the London Basin groundwater model. More detailed interaction between the two NRA modelling groups will result in more definitive resource values.

In addition, further investigations should be undertaken into the extent to which problems will arise with abstracted water quality due to leaking out of oxidised gypsum and pyrite products from the Basal Sands.

8.7.3 Abingdon/Drayton Reservoir

There is a need for more detailed data collection, and analysis and for establishing policy and preparation of expert evidence thereon in anticipation of the promotion of a major reservoir by TWUL at Drayton near Abingdon. This will almost certainly be the subject of a Public Local Inquiry (PLI) at which the NRA would be expected to take a prominent part. Areas of concern and interest to the NRA at such an inquiry will include:

a) determination of a justifiable prescribed residual flow (PRF) PRF for the proposed abstraction from the Thames near Culham to fill and refill the reservoir, together with a maximum acceptable rate of abstraction associated with it: also whether the abstraction is to be flow constrained,

b) consideration of whether instead of PRF's it might be preferable to link operation of the reservoir to a series of minimum environmentally acceptable flows for the catchment downstream to Teddington weir.

c) determination of the maximum acceptable rate of releases from storage to the river taking account of all relevant considerations including:-

    - fisheries and fishing
    - flood defence and land drainage
    - navigation and recreational uses of river
    - riparian users and owners' interests
    - health and safety
    - aquatic environment including visual amenity.

d) determination of requirements for operation of the reservoir and linkage to downstream abstraction licences and prescribed flows at Teddington weir, for inclusion in licensing,

e) water quality effects of storage, both in store and after release, especially from projection and application of the reservoir Farmoor data,

f) emergency planning measures involving:
   i) failure of an impoundment bund
   ii) emergency drawdown of reservoir water levels due to impending failure of a bund,

g) effects of reduction in winter flooding on downstream nature conservation sites where value relies on periodic flooding or water levels in general,

h) effects of the altered river regime and characteristics on river ecology, is particular whether temperatures, flow, sedimentation and substrate, the dominant variables controlling invertebrate distribution and fisheries, will be affected.

i) for h) to be accomplished surveys and monitoring of existing conditions need to be undertaken.

8.7.4 Severn-Thames Transfer

For this option there is a need for further consideration of:

a) works at both ends of the route especially the location and form of the receiving works at Buscot,

b) effects of bunded storage at Deerhurst and Buscot on floodplain management and flooding.

c) effects of Buscot discharges on land drainage in downstream areas,

d) impact of transfers on aquatic biology of the Thames including:

i) response of upstream migration of salmonids to changes in flow regimes,

ii) disruption of "homing" of salmonids,

iii) spawning requirements of fish in relation to flow velocities.

e) the residual flow to the estuary required by Severn-Trent Region,

f) water quality implications of the transfer, particularly with the size of the transfer now under consideration and with perhaps the need to store for a period after transfer and before release down the river.

8.7.5 Gravel Pit Storage

For this option there is a need to determine:

a) the likelihood of development of gravel workings at Down Ampney, in a form suitable for eventual use in the Severn transfer,

b) likely objections to eventual use of gravel pit for water storage,

c) flooding effects of loss of flood plains of the Ampney Brook.

8.7.6 Effluent Re-use

Issues which need further exploration include:

a) public perception of effluent re-use schemes of the type proposed, and measures required to gain public acceptability,

b) availability of land for additional effluent treatment works,

c) effects on 'homing' of salmonids via Teddington weir.

8.7.7 Anglian - Thames Transfer

The possible options here are at an early feasibility planning stage and depend on more work and refinements of assumptions in Severn-Trent and Anglian regions. Subject to that, NRA-TR will need to examine in more detail the relative advantages and other comparisons particularly as between the western transfer route to the Thame and the eastern transfer route to the Stort/Lee, and the resource potential of the Great Bradley reservoir.

8.7.8 Augmentation Losses

For all of the river augmentation options discussed in this report the yield/resource values have been based on notional losses during transfer downriver of 5%. It is important that these losses be considered in more detail, in the light of operational experience in Thames, Severn-Trent and Anglian regions, with more definitive use in refinement of these options.

BIBLIOGRAPHY

General

Sir William Halcrow and Partners	1991	Water Resources Planning - Strategic Options Draft Final Report National Rivers Authority
Thames Conservancy	1969	Water Resources Act 1963, Section 14, Report of Survey 1969, Thames Catchment Area and London Excluded Area. 121pp-1c.
Water Resources Board	1974	Water Resources in England and Wales, 2 vols. HMSO.
Water Resources Board	1987	Water Resources in South-East England, 2 vols. HMSO.
Department of the Environment	1986	River Water Quality in England and Wales, 1985. A report of the 1985 survey. HMSO.
Institution of Civil Engineers	1991	Water Supplies in the UK in the 1990's and Beyond. Thomas Telford, London, 28pp.
Binnie and Partners, and Oakwood Environmental	1991	Water for the Future in Kent: Issues and Options.
Water Research Centre	1977	Cost Information for Water Supply and Sewage Disposal Technical Report TR61, 627pp.
National Rivers Authority	1990	The Ely Ouse Essex Water Transfer Scheme
Department of the Environment	1991	The Potential Effects of Climate Change in the United Kingdom, HMSO, London.
Central Water Planning Unit	1980	Severn to Thames Water Transfers Summary Report. HMSO Amersham.
Water Services Association	1990	Water Facts

Demands

Thames Conservancy	1969	Water Resources Act 1963, Section 14, Report of Survey 1969, Thames Catchment Area and London Excluded Area, 121pp.
National Rivers Authority	1991	Demands and Resources of Water Undertakers in England and Wales. Preliminary Report under Section 143(2) (a) Water Act 1989. 40pp.
Russac, D.A.V., Rushton, K.R. and Simpson, R.J.	1991	Insight into Domestic Demand from a Metering Trial J. IWEM, Vol 5(3)
Keane, M.A. and Kerslake, J.C.	1988	The London Water Ring Main: An Optional Water Supply System J. IWEM, Vol 2(3)

Desalination

Water Resources Board	1972	Desalination for Drinking Water Supplies HMSO.

Resources

Jamieson D.G.	1984	Water Resources of the Thames Basin: Quantitative and Qualitative Aspects. Jln. Ins. Wat. Env. Sci: Vol 38(5). pp 379-391.
Montague, S.	1988	London 'must control' rising groundwater. New Civ. Engr. No. 813, 5.
Payne, J.A. Thomas, W.M., Cooke, J.E., and English, E.	1988	Groundwater Quality Beneath the City of London Overview and Long-term Changes. Jln. Inst. Wat. Env. Man., 1988, 2 No. 3. pp 305-310.
Marsh, T.J., and Davies, P.A.	1983	The Decline and Partial Recovery of Groundwater Groundwater Levels Below London. Proc. Inst. Civ. Engrs., Part 1, V 74, pp 263-276

Institution of Civil Engineers	1978	Thames Groundwater Scheme. Inst. Civ. Engrs., London 241 pp.
Naylor, J.A.	1974	The Groundwater Resources of the River Gravels of the Middle Thames. Water Resources Board, Reading, 45 pp.
Chisholm, F.A.	1984	Rising Groundwater Levels under Greater London and Their Geotechnical Significance. M.Sc. Eng. Geol., Imperial College, London
Simpson, B., Blower, T., Craig, R.N. and Wilkinson, W.B.	1989	The Engineering Implications of Rising Groundwater Levels in the Deep Aquifer Beneath London. CIRIA Special Publication 69.
Nield, T.	1986	Floods in Britain's Basement. New Scientist v 109, No. 1501, pp 26-29.
Smith, D.B. Downing, R.A. Monkhouse, R.A., Otlet, R.L. and Pearson, F.J.	1976	The Age of Ground Water in the Chalk of the London Basin. Water Resources Research, v 12, No. 3, pp 392-404

Gravel Workings

Ankett Associates	1991	Outline Planning Support Document Caversham Lakes, Henley Road, Caversham, Reading
Wiltshire County Council	1989	Wiltshire Minerals Local Plan Adopted Written Statement
Oxfordshire County Council	1988	Minerals Local Plan for Oxfordshire Draft for Consultation
Berkshire County Council	1990	Review of the Berkshire Minerals Local Plan. Draft for Public Consultation

Estuary Storage

Cockburne A.G. and Triggs D.M.	1982	Consideration on the use of the Thames Barrier to provide a Water Resource. Thames Water Authority Internal Report.

Thomas, G.A., and Sexton, J.R.	1985	Use of the Thames Barrier as a Water Resource Thames Water Authority Internal Report

Artificial Recharge

Boniface, E.S.	1959	Some experiments in artificial recharge in the Lower Lee Valley.—Proc. Inst. Civ. Engrs., v 14, pp 325-338.
Connorton, B.J.	1989	In: Recent Developments in Artificial Recharge of Groundwater, Water Supply 7, No. 2/3 5513, 1-21.
Flavin, R.J. and Joseph, J.B.	1983	The Hydrogeology of the Lee Valley and Some Effects of Artificial Recharge Quant. Jnl. Eng. Geol., 16, No. 1, pp.65-82.
Edworthy, K.J. Stott, D.A. and Wilkinson, W.B.	1978	Research Into the Effects of Artificial Groundwater Recharge, Lee Valley, London, England. Wat. Res. Bull, 14, No.3, pp 554-575
Water Resources Board	1974	Artificial Recharge of the London Basin. IV Pilot Recharge Works in the Lee Valley. Water Resources Board, Reading, 59pp.
Water Resources Board	1977	Artificial Recharge of the London Basin, IV. Pilot Recharge Works in the Lee Valley. Water Resources Board, Reading, 59pp.
Water Resources Board	1977	Artificial Recharge of the London Basin, IV. Pilot Recharge Works in the Lee Valley. Water Resources Board, Reading, 59pp.
Water Resources Board	1974	Artificial Recharge of the London Basin, III. Economic and Engineering Desk Studies. Water Resources Board, Reading, 64pp.
Water Resources Board	1973	Artificial Recharge of the London Basin, II. Electrical Analogue Model Studies. Water Resources Board, Reading, 1973, 46pp.

(Bibliography Contd.)

Metropolitan Water Board	1972	Artificial Recharge in the Lower Lee Valley RWA19.
Metropolitan Water Board	1972	Report on Artificial Recharge in the Lower Lee Valley, RWA31
Hawnt, R.J.E.	1981	Report on the Results of Field Monitoring by the Hydrology Section of Tests and Operations in the Lee Valley Artificial Recharge Prototype Scheme, 1976-1978, Thames Water Authority - 53.
Water Research Centre	1979	Report of Research into the Effects of Artificial Recharge in the Lea Valley. Water Research Centre - 19. ILR 1076, 38pp.
Liddament, M.W.	1977	Artificial Recharge in the Lea Valley. The Mathematical Model of the Groundwater System - Report No. 1 Water Research Centre - 32, ILR 667, 19pp
Liddament, M.W.	1977	Artificial Recharge in the Lea Valley. The Mathematical Model of the Groundwater System - Report No. 2, Water Research Centre - 33, ILR667, 19pp.
Liddament, M.W. &		Artificial Recharge in the Lea Valley. The Mathematical Model of the Groundwater System - Report No. 3, Water Research Centre - 34, ILR667, 17pp.
Cameron, R.J.		Artificial Recharge in the Lea Valley. The Mathematical Model of the Groundwater System - Report No. 4, Water Research Centre - 35, ILR667, 18pp.
Cameron, R.J. & Joseph, J.B.	1979	A One-Dimensional Model of the Effects of Artificial Recharge on the Basal Sands of the Lea Valle. Water Research Centre - 36, ILR 1030. 29pp.

(Bibliography Contd.)

Edworthy, K.J. & Joseph, J.B.	1979	Some effects of Artificial Recharge in the Lea Valley, London. Water Research Centre - 37, ILR 989, 21pp.
R. Flavin	1981	Borehole Investigation of North London: A Preliminary Study in the Assessment of the Feasibility of an Extension to the Lee_Valley Artificial Recharge Scheme. Thames Water Authority.
Connorton, B.J.	1984	The Enfield-Haringey Artificial Recharge Scheme, Project Appraisal, IRI 62, Thames Water Authority.

Environment

Alabaster, J.S & Lloyd, R	1982	Water quality criteria and freshwater fish. Food and Agriculture Organisation of the United Nations for Butterworth Scientific
Boon, P.J.	1988	The impact of river regulation on invertebrate communities in the UK. Regulated rivers: research and management, Vol. 2, 389-409.
Brewin, D.J & Martin, J.R	1988	Water quality management: a regional perspective - the Severn-Trent area. Regulated Rivers: Research Management, Vol. 2, 257-275.
Bryan, K.A	1982	An investigation of some factors influencing the performance of a recreational trout fishery. Journal of Applied Ecology Vol. 19, 113-131.
Bullock, A & Johnson, I.	1991	Towards the setting of ecologically acceptable flow regimes with IFIM. BHS 3rd National Hydrology Symposium Southampton.
Carling, P.A	1988	Channel change and sediment transport in regulated UK rivers. Regulated rivers: research and management, Vol. 2, 369-387.
Child, M.W & Mills, A.M.	1991	The benefits of environmental assessment. IWEM: Conference 1991.

(**Bibliography Contd.**)

Coles, T.F, Southey, J.M, Forbes, I. & Clough, T	1989	River wildlife databases and their value for sensitive environmental management
Cowx, I.G & Gould, R.A	1989	Effects of stream regulation on Atlantic salmon Salmo salar L., and brown trout, Salmo trutta L., in the upper Severn catchment, UK. Regulated rivers: research and management, Vol. 3, 235-245.
Cowx, I.G. Young, W.O. & Booth, J.P.	1987	Thermal characteristics of two regulated rivers in mid-Wales, UK. Regulated rivers, vol. w, 85-91.
Dobson, C & Cross, R.C.	1991	Operational control in a major river regulation system. BHS 3rd National Hydrology Symposium, Southampton.
Edwards, R. & Howell, R	1989	Welsh river and reservoirs: management for wildlife conservation.
Friday, L.A	1987	The diversity of macroinvertebrates and macrophyte communities in ponds. Freshwater Biology Vol. 18, 87-104.
Giles, D.M, Lowings, A & Midgley, P.	1988	River regulation by seasonal groundwater abstraction: the case of the river Itchen. Regulated rivers: research and management Vol. 2, 335-347.
Gore, J.A & Nestler, J.M	1988	Instream flow studies in perspective. Regulated rivers: research and management.
Guiver, K.	1976	Implications of large scale water transfer in the UK. Chemistry and Industry, 21 February.
Gustard, A.	1989	Compensation flows in the UK; a hydrological review. Regulated rivers: research and management, Vol. 3, 49-59.
Gustard, A. & Bullock, A	1991	Advances in low flow estimation and impact assessment. BHS 3rd National Hydrology Symposium, Southampton.

(Bibliography Contd.)

Hellawell, J.M.	1988	River regulation and nature conservation. Regulated rivers: research and management Vol. 2, 425-443.
Higgs, G. & Petts, G	1988	Hydrology changes and river regulation in the UK. Regulated rivers: research and management Vol. 2, 349-368.
Institute of Civil Engineers	1991	Water-Supplies in the UK in the 1990s and beyond.
Institute of Hydrology	1987	A study of compensation flows in the UK. Report No. 99
Irvine, J.R	1985	Effects of successive flow perturbations on stream invertebrates. Can.J. Fish. Aquat. Sci., Vol. 42, 1922-1927.
Jeffries, M. & Mills, D.	1990	Freshwater ecology - principles and applications. Belhaven Press.
Johnson, P.	1987	Introductory statement. Water projects: environmental and social aspects.
Johnson, P.	1988	River regulation: a regional perspective Northumbrian water authority. Regulated rivers: research and management. Vol. 2, 233-255.
Mann, R.H.K.	1988	Fish and fisheries of regulated rivers in the UK. Regulated Rivers: Research Management, Vol. 2, 411-424.
Mann, R.H.K., Blackburn, J.H & Beaumont, W.R.C	1989	Freshwater Biology, Vol. 21, 57-70.
Mason, C.F.	1991	Biology of Freshwater Pollution. Longman Scientific and Technical.
Moore, D & Driver, A.	1989	Conservation value of water supply reservoirs.
Munn, M.D & Brusven, M.A.	1991	Benthic macroinvertebrate communities in non-regulated and regulated waters of the clearwater river, Idaho, USA. Regulated rivers: research and management, Vol. 6, 1-11.

(Bibliography Contd.)

National Rivers Authority	1991	NRA to apply 'absolute limits' for pollutants. News Release, September.
Ormerod, S.J. & Edwards, R.W.	1987	The ordination and classification of macroinvertebrate assemblages in the catchment of the River Wye in relation to environmental factors. Freshwater Biology Vol. 17, 533-546.
Pearce, F.	1991	Pipe dreams to quench Britain's thirst. New Scientist 16 November.
Petts, G.E.	1984	Impounded Rivers - Perspective for Ecological Management. Wiley-Interscience Publication, John Wiley and Sons.
Petts, G.E	1988	Accumulation of fine sediment within substrate gravels along two regulated rivers, UK. Regulated rivers: research and management Vol. 2, 141-133.
Petts, G.E.	1988	Regulated rivers in the United Kingdom. Regulated rivers: research and management, Vol. 2, 201-220.
Price, D.R.H		Environmental impact assessment as practised by Anglian Water Services Ltd.
Reynolds, C.S., White, M.L., Clarke, R.T & Marker, A.F	1990	Suspension and settlement of particles in flowing water : comparison of the effects of varying water depth and velocity in circulating channels. Freshwater Biology Vol. 23-34.
Severn to Thames transfer working group		Amendments to draft final report (Fisheries, Recreation, Ecology). NRA Thames report. Not published.
Smith, C.D., Harper, D.M. & Barham, P.J	1990	Engineering operations and invertebrates; linking hydrology with ecology. Regulated rivers : research and management Vol. 89-96.
Swales, S	1988	Fish population of a small lowland channelised river in England subject to long-term river maintenance and management works.
Water Quality Survey Group	1990	Proposals for formulating statutory quality objectives.

(Bibliography Contd.)

Watson, D	1987	Hydraulic effects of aquatic weeds in UK rivers. Regulated rivers : research and management, Vol. 1, 211-227.
Weston, A.E & Hodgson	1991	The River Aled regulation system - reconciling the reconcilable. BHS 3rd National Hydrology Symposium, Southampton.

APPENDIX 1

TERMS OF REFERENCE

26-12

HHP. LEATHERHEAD

RECEIVED

2 [illegible] 1991

ACTION	INIT	DATE
LSSA		
DI		24/6/91
FILE REF	314-01-60	

National Rivers Authority
Thames Region

NRA

Date

21 June 1991

Howard Humphreys & Partners Ltd
Thorncroft Manor
Dorking Road
LEATHERHEAD
Surrey KT22 8JB

Attention: Mr L J S Attewill

Direct Line: 0734 535387

Dear Sir

1. You are invited to submit proposals in accordance with the enclosed technical brief and as further detailed below.

2. Three copies of the proposal are required by 12 noon on Monday 15 July, 1991. Please note alteration of submission date from earlier correspondence.

3. The detailed proposals should include the following:-

- why the consultant should be chosen for the project; what experience and specialist skills the company can contribute to the study

- what information the consultant would expect to need and where you would look for this information

- how the consultant proposes to carry out the study, including views on the practicability, any areas of difficulty and how the latter will be resolved

- a schedule of rates for project staff

- total man-months input for each key activity

- staffing proposals with brief c.v.'s of key staff

- confirmation that the project staff will be available assuming an early August start date

- proposed method of payment

Kings Meadow House Kings Meadow Road Reading Berks RG1 8DQ. Tel: Reading (0734) 535000. Telex: 849614 NRATHA G. Fax: (0734) 502974

4. In addition the consultant may submit a brief executive summary focussing on what particular suitability they have to undertake the study.

5. We would welcome your comments on the techical brief and any proposals towards the success of the project.

6. We are adopting the World Bank, two envelope submission procedure, i.e. one envelope contains the technical submission and resourcing, the other contains the financial submission. Each envelope must be clearly marked and placed in the envelope provided. This envelope shall bear no distinguishing matter or mark intended to indicate the identity of the sender. Any tender received after that date and time may not be considered.

7. The employer shall not be liable for any expenses incurred by the Tenderer in preparation of this tender.

8. The proposed duration of the study is six months and it is intended to let the contract to the selected consultant in early August 1991.

9. Brief progress reports will be required on a monthly basis.

10. Six copies of progress reports and 15 copies of final reports will be required.

11. We propose, as the contractual basis for the study, to appoint the consultant using the form of Agreement for Reports and Advisory Work, as published by the Association of Consulting Engineers.

12. Please confirm your intention to bid, by telephone or facsimile, within 3 days of receipt of this invitation.

13. We may wish to discuss your submission; we have scheduled time on 24 and 25 July and will contact you if the need arises.

On receipt of this letter please send, by return post, a statement of your previous year's accounts.

Should you have any queries please contact Brian Arkell or Carolyn Ingles on the above telephone number.

Yours faithfully

DR G W PHILLIPS
Catchment Control Manager

NRA

NATIONAL RIVERS AUTHORITY - THAMES REGION

WATER RESOURCES DEVELOPMENT OPTIONS

Technical Brief for Study Project

1. Introduction and Objective

1.1 The Thames Region of the National Rivers Authority (NRA) is responsible for carrying out the NRA's catchment management functions for the River Thames, its tributaries and associated river basin. These functions are defined in the Water Act 1989 and include Water Resources regulation and management.

1.2 The Water Act in s.125 (1) places a duty on the NRA "to take all such action as it may from time to time consider... to be necessary or expedient for the purposes (a) of conserving redistributing or otherwise augmenting water resources in England and Wales, and (b) of securing the proper use of water resources in England and Wales". Furthermore in s.143 (2) the NRA is required "to collate and publish information from which assessments can be made of the actual and prospective demand for water, and of actual and prospective water resources, in England and Wales".

1.3 As a step towards fulfilling these duties, the NRA nationally has (i) initiated arrangements for collecting and collating data on demands for water and on water resources, region by region, and (ii) commissioned a consultancy project to identify and appraise strategic options for water resources development to meet estimated deficiencies for public supplies to the year 2021 as a national overview.

1.4 This paper concerns a proposed project for the Thames Region of the NRA. The project is required to relate to and take account of the national overview study referred to above, and carry forward the identification of potential solutions to a further stage of detail for the Thames region including costing and a balanced environmental evaluation. The consultants will be required to consider the future resource needs of the public supply companies and the resource development options available for meeting them, together with making provision for the needs of industry and agriculture and for environmental and other in situ requirements and constraints.

1.5 NRA Thames Region are looking to the consultants for expertise in helping to identify and prioritise alternative development options. There are no simple alternatives; costs should not be the dominating factor in prioritising the alternatives. As such in the general programming of the project we would anticipate input divided along the lines of 10% - 20% NRA Thames Region; 70% Consultants identifying and evaluating options, 10% other organisations where necessary.

1.6 It is planned that this study, which may be followed up with further work on specific aspects as later deemed necessary, should be completed in 5 to 6 months from the date of instruction to proceed.

1.7 The Terms of Reference are set out in Annex 1 and the requirements are more fully described in the remainder of this Technical Brief.

2. Resource/Demand Balance : Present and Forecast Situation

As part of its duties under S.143 of the Water Act 1989, NRA-Thames Region has collated information on existing resources and demands, forecast demands 2021/22, and proposed resource developments to meet anticipated deficits to this time horizon. Information is also maintained on direct abstractions.

The consultants will be provided with the following information:

- information on the current resource/demand balance for each water supply company, split where possible into supply areas.

- forecast demands, planned and proposed resource developments, continued deficits.

NB. The Authority maintains its own population data system, accounting for latest estimates of population change, and this data is provided to all the companies within the Region to ensure some consistency in their forecasts.

- industry and agriculture: direct abstractions, and anticipated needs. These may be categorised into:

  - Industry: cooling, evaporative, process uses
  - Agriculture: through-put (fish farms, cress beds)
    consumptive (spray irrigation).

  From this, it is anticipated that the consultants will be able to take a view of estimated future demands and corresponding deficiencies for each of the main supply areas.

  Thames Region already maintains and runs a detailed regional water resource model allowing for the full evaluation of resource-abstraction-effluent return effects. This may be used from time to time for further detailed evaluation of proposals considered.

  The consultants may identify a need for simple models to evaluate options given a range of hydrological scenarios.

3. Environmental and other In-situ Requirements and Constraints

3.1 The Consultants are required, in liaison with NRA-Thames Region Water Resources Strategy Group and any other disciplines/organisations necessary, to identify in-situ environmental requirements and development constraints of each resource development option. Prior to consultation with the above bodies and organisations and NRA departments, a report on the issues to be raised during each consultation should be forwarded to the client for comment before proceeding.

3.2 The NRA Thames Region is currently aware of many areas where further development is seriously constrained. This includes areas identified as low flow catchments suffering substantially as a result of groundwater abstraction.

3.3 The Consultants should also be aware that there are a number of internal licensing policies which are used in the determination of licence applications. Although not formally written down, the successful consultant will be made fully aware of these policies.

3.4 Following the consultations as outlined above with environmental and other interests within and outside the NRA region, the Consultants are required to make an outline assessment of the overall river flow, groundwater level and water quality requirements for the main river reaches, principal tributaries and critical aquifer areas of the Thames Catchment. This should be discussed with the client, to provide an agreed basis for further work.

3.5 Generally within the Thams Region the NRA could not accept further surface water abstraction without the provision of storage and the protection of a prescribed minimum flow. Similarly there are few opportunities for the major development of groundwater in the region except artificial recharge and near to the larger rivers and where the resource is recirculated. In the latter case flow constraints may be required.

4. Water Quality considerations for abstracted users

4.1 In addition to the water quality requirements and constraints arising from environmental and other in-situ considerations, the consultants will be required to give particular attention to water quality requirements for public supply and direct industrial requirements. These will include the ability to comply with the EEC Directive on surface sources used for Drinking Water Supplies, acceptably low concentrations of Red List Dangerous Substances, conditions which may encourage algal blooms etc. In addition, where transfer or conjunctive use of waters of differing origin and chemical constituents are involved, it is necessary to ensure that water quality variations do not exceed tolerance thresholds both for treatment and for consumers in general.

4.2 As with demand forecasts, the Consultants will be required to seek information on pre-treatment water quality requirements and options from the public water supply companies, and in the case of direct abstractions, from the appropriate representative organisations such as the CBI and NFU. Thames NRA will endeavour to seek the cooperation of the other parties involved in ascertaining water quality requirements.

5. Water Resource Development Options

5.1 The preceding stages of the study are needed to give a qualified assessment of the component and total resource development requirements for abstracted and other licensable water, together with constraints placed upon such development and abstraction for environmental and other in-situ reasons, and by quality requirements for abstracted uses.

5.2 This stage involves the identification and assessment of development options. These may be considered under the following headings:-

A. Resources in the Thames Catchment based on surface run-off and natural groundwater recharge.

(i) Purpose-built reservoirs, either

(a) new sites, or
(b) enlarged and/or redeployed existing ones.

TWUL have announced proposals for a reservoir feasibility study on a site west of Abingdon, they have also identified redevelopment of the Staines reservoirs as a resource option. It is anticipated the benefits of any alternative sites or redevelopments identified by the consultants will be compared with those already proposed by TWUL or the Water Companies. The Consultants will be provided with information to hand at the time to compare and contrast with alternative options. We do not anticipate the Consultants will need to revisit these proposals.

(ii) Existing gravel workings modified and used for storage with or without extension.

The consultants should evaluate existing and potential sites for winter flow storage, proposed developments such as Caversham Lakes should be included in the study. A statement should also be made concerning suitability for direct supply or summer flow augmentation from these resources. In addition the environmental implications to groundwater flow of developing such resources must be addressed.

(iii) River abstractions with storage where flows are constrained by a prescribed minimum flows as identified in 3.5. The opportunities for this are unlikely to prove viable within this region.

(iv) Groundwater abstraction

(a) direct supply (baseload or intermittent)
(b) intermittent low flow augmentation.

B. Resources transferred into the Thames Region

(i) Severn-Thames transfer including supporting storage which may be in Wye, Severn or Thames catchments. A starting point will be the WRB and CWPU desk studies. The Consultant will be required to review and recost the complete scheme and any other options identified.

(ii) Transfer from a site which might be available from Anglian Region. A number of proposals have been discussed in the past. These will provide a starting point for further study. The consultants should assume joint regional development of proposals and yield scenarios of 100 to 300 Ml/d available to Thames Region.

(iii) NRA Thames Region is unaware of any proposals in the Wessex or Southern Regions, but the Consultants should take a brief look at the situation to confirm this is the case.

C. Re-use of Effluents

There are significant volumes of effluent contributed to the tideway. The consultants are asked to consider opportunities for better use:

(a) discharged treated to rivers to augment flows upstream of abstraction and storage or discharged direct to reservoirs.

(b) used treated effluent direct to meet lower grade (non-potable) requirements. Discussions may need to be held with the CBI to determine likely industrial uses and sites.

D. Other Resources

(i) Artificial recharge of groundwater using either

(a) Thames derived water, or

(b) imported water including conveyance by sea which may obviate the need for pre-treatment.

(ii) Estuarial storage i.e. below tidal limit storage of fresh water run-off. The Consultants should be aware that in the past the Thames Barrier has been considered for this. The option has been rejected for a variety of reasons, most pertinent of which was rising groundwater levels in London and obstruction of navigation.

(iii) Desalination of sea water.

(iv) Other options.

5.3 It should be noted that Demand Management is to be regarded as an aspect of demand forecasts and therefore does not feature above as a potential "resource" to off-set deficiencies.

5.4 The Consultants are required to identify specific outline proposals under all of the above categories of resource development. The proposals should include a balance to enable rejection, with confidence, of options which are not viable or explore and justify practical options. The potential for development should be assessed under the following headings:-

- technical feasibility
- water resource yield
- environmental considerations
- water quality consideration
- economic and cost considerations
- mode of operation, control rules etc.
- balance of benefits and disbenefits

6. Final Report

6.1 The Consultants are required to conclude the study project with a report covering the three elements of the work outlined above, viz

- a simple summary of present water resource/demand balance and future deficiences.
- detailed development options assessed on a broadly consistent and objective basis. This could with advantage include a numerical ranking from say 1 to 10 to indicate a general quantification of preferences together with the perceived balance of benefits and disadvantages and any significant uncertainties. Where appropriate the consultants should demonstrate their findings with graphical presentations.

- proposals for additional studies which in the Consultants' view would be necessary prior to development.

- identification of the long term regional strategy

6.2 The Consultants are asked to submit a programme for the Project at the proposal stage. This should allow for the submission of a draft of the final report to the NRA Thames region for comment and feed-back four weeks prior to the date for final submission and completion of the project.

ANNEX 1

NRA - Thames Region : Water Resources Planning Study

Terms of Reference

1. Carry out a water resources planning and development study for the National Rivers Authority - Thames Region, including identification and assessment of options to meet estimated future demands for abstracted water for all purposes within the region.

2. Collate and review (i) resource yield assessments at prevailing levels of development, and (ii) future demand estimates for public supply and other abstracted purposes to the year 2021 at 10 yearly intervals as provided to the Consultants by the NRA.

3. Review water quality requirements for abstracted uses and the extent that these may be a constraint on resources development.

4. Review the range of feasible water resources development options for meeting future deficiencies to 2021, taking due account of environmental and water quality aspects. Provide a broad indication of relative costs together with environmental benefits and disbenefits of various options.

5. The sensitive nature of the results and the likely need to use the results as evidence at Public Inquiry, requires that the project should be viewed as confidential to NRA - Thames Region and no data should be passed on to third parties, or published in any form, without the prior written agreement of the Project Sponsor.

6. Liaison with NRA staff or other consultants should be carried out through the Project Sponsor. Progress meetings will be held monthly to report on development and findings.

7. An interim report will be required within two and a half months defining areas of need/deficit; environmental constraints including in-situ flow requirements of resource development options.

8. A draft final report will be prepared at 5 months leading to a final report at 6 months. This should include findings and recommendations on the matters referred to above as amplified in the Technical Brief.