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NRA-Thames Region

Water Resources Strategic Scheme Development Options Technical Overview

June 1993

ENVIRONMENT AGENCY
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NRA

PREFACE

This report is the first of a series that will summarise strategic water resource issues in the Thames Region. It aims to provide a summary of the engineering options feasible to meet future growth in demand within this region and addresses the key issues in terms of engineering, cost and environmental impact. No attempt is made in this report to propose any strategy or timescale of development. I invite constructive comments on the report.

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June 1993

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Water Resources Strategic Scheme Development Options
Technical Overview

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EXECUTIVE SUMMARY

Scope

This report summarises work carried out in association with consulting engineers Howard Humphreys & Partners and environmental consultants Cobham Resource Consultants during 1991/2. The scope of work towards this report, essentially a desk study, was to identify and appraise all engineering schemes which could be included within a strategy for the region to such a degree that schemes could be developed when necessary or scheduled in the light of successes in demand management and/or changing demand forecasts. The report concentrates on the identification of potential engineering schemes, capital costs and environmental issues. Two further reports will follow on: the question of 'need' and the role of demand management; and water resources strategy for the region.

This study has focused on the planning and promotion of schemes with an aggregate resource value of 500 Ml/d providing appropriate time to refine demand forecasts, yield and use of existing resources and the timing and need of resource developments.

The report identifies a range of possible schemes, including those which are being actively investigated by water companies. Following a 'broad brush' assessment of engineering, cost and environmental feasibility, a number of options were examined in greater detail. These included:

- the ongoing development of London Basin groundwater options -artificial recharge and rising groundwater in Central London;
- new riverside groundwater sources in the middle Thames area and middle Kennet around Newbury, some of which are currently being investigated;
- new or redeveloped reservoir storage and river regulation schemes;
- schemes for 'managed' re-use of treated sewage effluent;
- inter-regional transfer schemes via the Severn Trent and Anglian regions.

Summary

Schemes currently under investigation/development within the London area (artificial recharge, rising groundwater, etc) should be pursued with vigour to make up for the existing deficit in resources. Investigations of potential riverside groundwater sources elsewhere in the catchment are currently in progress. However, any further abstraction from groundwater will be constrained by river flow in order to protect other users and the river environment.

The 'managed' re-use of sewage effluent in the London area is feasible in engineering terms but there remain concerns as to the public acceptability of the practice on a frequent basis. Further detailed investigations are required to satisfy environmental interests, regulatory and drinking water requirements.

A detailed survey of potential reservoir sites within the region has already been undertaken by Thames Water Utilities Limited (TWUL) and this report does not attempt to repeat that work. The proposed south west Oxfordshire reservoir near Abingdon has been compared against other development options not alternative reservoir sites. In terms of enlarging existing reservoir storage, NRA understand that work carried out by TWUL has shown this to be infeasible because of engineering constraints of the existing structures which would require complete replacement raising a host of environmental impact, engineering and cost issues.

No single scheme could provide as large a yield as is considered to be available from the (TWUL) proposed south west oxfordshire reservoir (300 Ml/d), nor would individual schemes provide the regional or strategic resource benefits that could be gained from this proposal. Conjunctive management of the reservoir with existing sources could provide environmental gain without loss of resources to the supply companies and provide benefits to other abstractors in the Thames catchment through supporting resources by augmentation or through bulk supply links.

Transfers from the Anglian Region (up to 200 Ml/d) could provide an economic alternative for resources to London and the north-east of the region. This option however would only be practical if forecast demand increases elsewhere in the Thames Region were not realised, for example if an enhanced level of demand management was applied across the region. It also depends upon proving extra resources are available from the River Trent for transfer into the Anglian Region.

Transfers from the Severn to the Thames (up to 400 Ml/d) would only be viable if supported by storage within the Thames Region to provide security of quality and yield. Options previously studied which discharged to the Upper Thames tributaries have been eliminated on environmental grounds.

Water quality and environmental impact remain concerns in terms of river to river transfers and augmentation schemes. Separate studies are currently underway to assess the extent of any impact and should continue.

It should be emphasised that the implementation of any of these options will be dependent on the degree to which demand management can offset the underlying growth in demand. Each option will have a distinctive profile in terms of its economic, environmental and social sensitivity; assessment of this profile should also include the effect of implementation of any one option on the profile of the remaining options.

Consideration of these profiles and their long-term effects will guide understanding of how the sustainability of water resources for the Thames catchment is to be achieved.

1.0 INTRODUCTION

1.1 The following report summarises work carried out by the National Rivers Authority (Thames Region) in association with Howard Humphreys & Partners Ltd (referred to hereafter as HHP) and Cobham Resource Consultants during 1991/92 to identify and assess feasible water resource development options to meet projected demands for water in the Thames Region to 2021. This study can be seen as a preliminary, strategic 'sifting' process from the NRA's vantage point.

1.2 This report concentrates on the identification of potential engineering schemes to meet anticipated water resource deficits as identified by the water companies within Thames Region. The question of 'need' and the role of demand management in future resource scenarios is not addressed in this report but will be the subject of a subsequent report. The primary purpose of this report is to identify and appraise schemes which would be capable of meeting all future 'unfettered' demands for water; any gains made in demand management will provide the benefit of delaying the need for schemes. The construction timescale of the schemes ranges from 2 to 10 years. Planning solely on the basis of ambitious or uncertain demand management achievements carries with it the risk of bringing forward at short notice the need for new schemes, the promotion of which is not always straightforward or timely.

1.3 No provision has been made within this water resources study to mitigate environmental effects (except for certain identified low flow catchments) or to meet water quality improvements.

1.4 The NRA national study indicated deficit forecasts requiring the need for development options with an aggregate yield of 1000 Ml/d for this region within the next thirty years, ignoring schemes that have been or are being developed. This study has focused on the planning and promotion of schemes with an aggregate resource value of 500 Ml/d giving appropriate time to refine demand forecasts, yield and use of existing resources and the timing and need of resource developments.

1.5 The purpose of this technical report is to explore the engineering, cost and environmental feasibility of the various water resources development options open to the region. It represents a progress report on technical issues and will be followed by companion reports on demands forecasts, the principals of sustainable development of the water environment and associated strategic issues, demand management and need for new resources; these taken together will be the source material from which to establish a water resources strategy for the Thames Region.

2.0 OPTIONS

2.1 The range of options identified in the study has not changed significantly from those recognised during the promotion of the Teddington flow proposal (see table 1).

2.2 A range of options has been broadly examined in relation to technical feasibility, yield, cost and potential environmental impact to provide a shortlist of those schemes with most development potential (see table 2);

Options already being planned:

* London Basin groundwater including artificial recharge conjunctive use;

* Riverside groundwater development;

* Reservoir storage in the Thames Region.

Other options:

* Use of gravel workings for storage;

* Re-use of effluents presently discharged directly to tidal Thames estuary;

* Redevelopment of Staines Reservoirs;

* Freshwater storage in tidal Thames estuary;

* Transfers from R. Severn to Thames;

* Transfers from Anglian Region to Thames catchment including onward transfers from the R. Trent;

* Transfers from further afield including from Wales (R. Wye), Northumbria (Kielder) and Scotland;

* Desalination of seawater;

* Kielder-London submarine (North Sea) pipeline.

3.0 OPTIONS NOT CONSIDERED FURTHER

3.1 Freshwater storage in the tidal Thames estuary

The use of the Thames Barrier as a barrage has been considered on several occasions over the last decade and was the subject of three desk studies by Thames Water Authority between 1980-82. Such a scheme is estimated to have a resource value of 200 Ml/d and could facilitate navigation upstream of Woolwich, increased minimum water depth (mudflat inundation) and possibly provide aesthetic, recreation and fisheries benefits.

However, the disadvantages of this scheme far outweigh the benefits;

* rise in groundwater levels which affect building stability and underground services;
* free access to navigation through the barrier denied;
* increase in flooding risk;
* impact on Syon (Park) Site of Special Scientific Interest (SSSI) due to salinity changes.
* risk from storm discharge pollution

3.11 Storage downstream of the barrier has also been considered but is not feasible due to the need to retain an unimpeded tidal channel for flood dispersion.

Off-channel bunded storage would require a site where there is little present development, i.e. well down the estuary at Tilbury or Gravesend. This could result in much higher unit costs for pumping and transferring water as compared with up-river storage.

3.12 Given the overall disadvantages discussed above and the limited river management, water resource and supply benefits, this option was not pursued further.

Table 1. **Extract from 'Teddington Flow Proposal - Statement of Case' (TWA 1986)**

Results of Assessment of Options

Option	Resource benefit (tcmd)	Unit cost[a] (£'000/ tcmd)	Earliest date achievable	Envir-onmental impact
Teddington Flow Proposal	170[b]	6	1986	minimal
Groundwater Scheme Stage II	70	330	1991	moderate
Redevelopment of Staines reservoirs	30	150	1991[c]	small
Artificial recharge Enfield-Haringey	90	110	1993	small
Redevelopment of King George reservoir (Lee Valley)	30	330	1993[c]	small
Artificial recharge south London	90	110	1995	small[d]
Demand management (variable flush)	60	270	1996	minimal
Re-use of Deephams effluent	100-150?	20[e] 60[f]	1996?	small – [g] moderate
Tidal barrier				
– half tide:	110?	350-500?	1996?	large
– full tide:	220?	250-400?	1996?	very large
Desalination	130[h]	400?	1996?	large
New reservoir	140[h]	500	2000	very large
Severn-Thames transfer	200	480-750	2000	very large
Gravel pits	i	200?	i	small

Footnotes

a indicative only
b varies over time
c depends upon other resources
d but feasibility yet to be established
e if activated carbon already installed at water treatment works
f if activated carbon treatment needs to be installed to allow re-use
g but water quality concerns
h size could be variable
i very small resource value – only suitable for emergency use. Date not applicable.
? denotes a particularly uncertain entry

Table 2. Preliminary comparison of potential development options

OPTION	POTENTIAL YIELD (Ml/d)	COST	ENVIRONMENTAL IMPACT
Abingdon Reservoir	300 (75 - 140 Mm^3 storage)	Mod	Mod
Redevelopment of Staines Reservoir	70	Low	Low
Riverside Groundwater development	70	Low	Mod
London basin Groundwater incl. Central London Aquifer Artificial recharge	180 (Base) 240 (Peak)	Low Low	Low Low
Storage in gravel workings	? (>150 Mm3 storage)	Mod	Mod
Re-use of effluents (Mogden and Deephams schemes)	800 (Max.)	Mod	Low
Estuarial storage - Thames Barrier	200	Mod-High	High
Transfer from Severn	700	Mod	Mod
Transfers from Anglian region	200 - 300	Mod	Mod
Transfer by Sea from Scotland/Kielder	? (100 - 200 possibly)	High	Low
Kielder - London Submarine pipeline	200	High	?
Desalination	?	High	High

3.2 Transfers from Wales, Northumbria and Scotland

Such transfers would only be viable if a reliable source of good quality water could be provided (thus minimising storage and treatment costs) to compensate for the high transmission costs.

3.21 Transfer from R. Wye to the Upper Thames

Two options have been considered;

i) Transfers supported by regulating storage in the upper Wye catchment.
ii) River transfer from lower Wye constrained by a prescribed minimum flow, balanced by storage in the Thames catchment.

The constraints of both options are broadly similar. With the exception of supplying the Thames Region needs, a reservoir in the Wye valley would not be required. In addition, the Wye tends to have a rather 'flashy' flow regime, therefore, low flow frequency would be an issue in assessing reliability. Other issues considered included water quality and transfer feasibility to the upper Thames. The preferred transfer aqueduct route would pass eastward to cross the Severn near Gloucester to Staverton and follow a route similar to the Central Water Planning Unit (CWPU) route 4 (1980). The Forest of Dean lies directly in line of any potential transfer route and the most convenient abstraction point is near to the scenic village of Ross-on-Wye which currently supports excellent R. Wye fisheries, including salmon, which would require variable and substantial residual flow. It was concluded that the option should not be pursued further since it provides a smaller transfer volume than the Severn-Thames transfer and would require a longer, more costly transfer route with greater environmental impact.

3.22 Imports from Northumbria (Kielder) by river and aqueduct

Kielder Reservoir constitutes the largest surplus water resource capacity in England and Wales. Transferring large volumes of water over long distances will result in extremely high transmission costs unless rivers are harnessed for the purpose. The transmission system could be extended from the present end point on the Tees into the Yorkshire Grid and further south to Anglian Region via the Humber either directly or by substitution southwards of existing resources. The high capital and operating costs of this option makes it uncompetitive compared to river to river transfers.

3.23 Imports from Northumbria or Scotland by Sea

The areas considered were the mid reaches of the R. Tyne (regulated by Kielder) and good navigable estuaries on the east coast of Scotland, i.e. Forth and Tay. The cheapest method was found to be towing butyl drogues behind ocean-going tugs. This, however, was found to be expensive compared to other resource development options with few compensating advantages and therefore the option was not pursued further.

3.24 Kielder-London Submarine pipeline

This scheme has been raised separately by consultants and was not specifically investigated as part of this study. Although potentially very costly, this scheme has the major advantage of speed of construction (approximately 3 years). Such a pipeline could supply 100-200 Ml/d from Tynemouth to a storage reservoir and treatment facilities on the Thames estuary, for example at Tilbury in Essex so that the water could then be fed into the London supply system. Numerous pipeline routes dissecting the North Sea are feasible, however, it is critical to take the shortest route through the North Sea gasfields. Boosting stations could be located on off-shore platforms or on-shore, the latter providing opportunities for supplying intermediate areas such as East Anglia. Operational links into the various water companies would need to be investigated. Although the scheme is being reviewed nationally costs make it viable only in the absence of other regional options.

3.3 Desalination of Sea Water

Whilst the costs of desalination plants are becoming more competitive, there remain certain disadvantages in their development for the scale of water resource need in the south-east of England. Desalination plants require consistent water quality, consistent water levels, low pollution risk and available land. These constraints dictate sites away from the Thames Estuary, i.e. Essex, South Coast. Desalination is an energy intensive process and therefore a significant amount of cheap power needs to be readily available. A substantial amount of saline waste flow is produced making this option relatively "environmentally unfriendly".

Other disadvantages include:

- the practicalities of locating a thermal distillation process in the Thames Region given the limited extent of unpolluted coastline suitable for a sea water intake that would be close enough to power stations to harness waste heat;

- the requirement of the reverse osmosis process for consistent water quality to avoid damage to the membranes;

- the need to bring the product water up to existing potable quality by blending and chemical dosing to overcome the low dissolved salts content, incurring additional costs.

In conclusion, high transmission, operation, power and production costs make desalination an uncompetitive resource option at this stage.

4.0 PURSUED OPTIONS

Figure 1 shows those strategic options considered further to meet the needs of Thames Region. Tables 3 and 4 compare these options in terms of their environmental impact and cost. Further details of environmental and engineering considerations are given in Appendix A and B.

4.1 London Basin Groundwater

Several schemes are being investigated (see figure 1):

* North London Artificial Recharge scheme;
* South London Artificial Recharge scheme;
* additional licensed groundwater abstraction which could also serve to control rising groundwater.

There also remain a number of existing licensed sources which have yet to reach their full potential.

The operation of both the South London and North London schemes would rely on regular aquifer recharge (during times of surplus) and intensive abstraction during dry/drought periods approximately once in every 7-10 years.

Figure 1. Thames Region Strategic Options

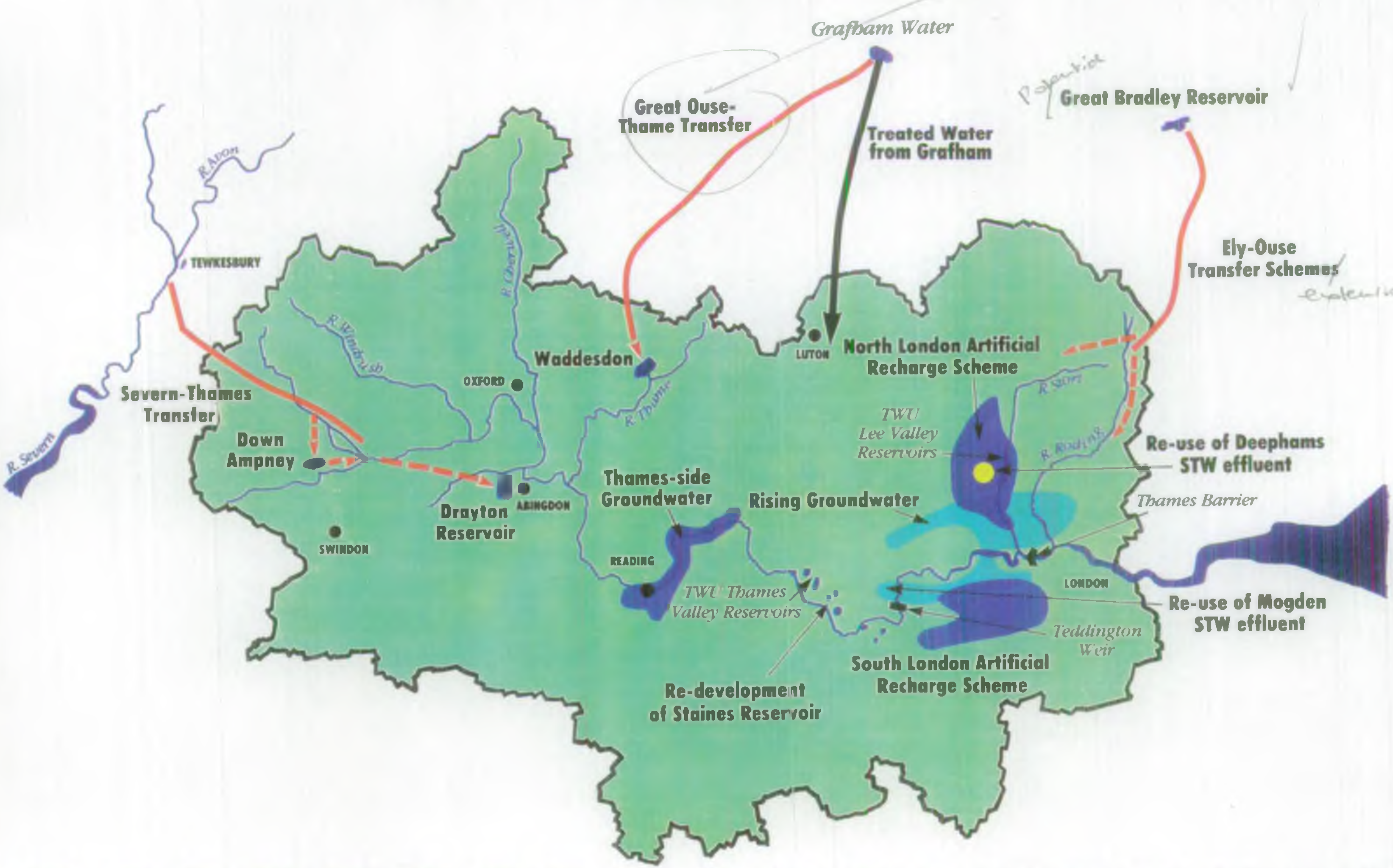


Table 3. Environmental comparison of options

Option/Sub-option	Phase	Planning/ Development		Agriculture/ Drainage		Landscape/ Visual Impact		Recreational Amenity		Archaeology/ History		Terrestrial Ecology		Aquatic Ecology		Fisheries	
		Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben	Dis	Ben
a) Riverside Groundwater	Con	0	0	0	0	Low	0	Low	0	0	0	0	0	0	0	0	0
	Op	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) London Basin	Con	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Op	0	Mod	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Abingdon/Drayton Reservoir	Con	Mod	0	Mod	0	High	0	Mod	0	Mod	0	Mod	0	Low	0	0	0
	Op	Mod	0	Mod	0	Low	Low	Low	High	0	Mod	0	Mod	Low	Low	Low	0
d) Redevelopment of Staines Reservoir	Con	Mod	0	0	0	Mod	0	Mod	0	Low	0	Low	0	High	0	0	0
	Op	Mod	0	0	0	High	0	0	0	0	0	0	0	Low	0	0	0
e) Re-use of Effluent	Con	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Op	0	0	0	0	0	0	Low	0	0	0	0	0	Low	0	0	0
f) Severn-Trent Transfer																	
i) To Abingdon/Drayton reservoir	Con	Mod	0	High	0	High	0	Low	0	Low	0	Low	0	0	0	0	0
	Op	Low	0	Low	0	Mod	0	Low	0	0	0	0	0	Mod	0	Mod	0
ii) To Buscot - 400 Ml/d	Con	Mod	0	High	0	High	0	Low	0	Low	0	Low	0	0	0	0	0
	Op	Low	0	Low	0	Mod	0	Low	0	0	0	0	0	Low	0	Low	0
g) Anglian Region Transfer																	
i) Thame transfer	Con	High	0	High	0	High	0	Mod	0	Low	0	Low	0	0	0	0	0
	Op	Low	0	Low	0	Mod	0	0	0	0	0	0	0	Low	0	Low	0
ii) Stort transfer - 200 Ml/d	Con	Mod	0	Mod	0	Mod	0	0	0	Low	0	Low	0	0	0	0	0
	Op	0	0	0	0	0	0	0	0	0	0	0	0	High	0	Mod	0
- 100 Ml/d	Con	Mod	0	Mod	0	Mod	0	0	0	Low	0	Low	0	0	0	0	0
	Op	0	0	0	0	0	0	0	0	0	0	0	0	Mod	0	Low	0
iii) Roding Transfer	Con	0	0	Mod	0	Mod	0	0	0	Low	0	Low	0	0	0	0	0
	Op	0	0	0	0	0	0	0	0	0	0	0	0	High	0	High	0
iv) Increase in Grafham water use	Con	0	0	0	0	0	0	Low	0	0	0	0	0	0	0	0	0
	Op	0	0	0	0	0	0	Low	0	0	0	0	0	0	0	0	0
h) Storage with Transfers																	
i) Waddesdon Reservoir	Con	Mod	0	Mod	0	Mod	0	Low	0	Low	0	Mod	0	0	0	0	0
	Op	0	0	Low	0	Low	Low	0	Low	0	0	0	Low	0	0	0	0
ii) Down Ampney Reservoir	Con	Mod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Op	Mod	0	Mod	0	0	0	0	0	0	0	0	0	0	0	0	0

Where 0 = no significant impact, positive or negative (Con=Construction phase, Op=Operation Phase, Ben=Benefit, Dis=Disbenefit)

Table 4. Comparison of Strategic Resource Development Options

Option/Sub-option			Maximum Yield Ml/d	Additional Resource Value Ml/d	Capital Cost* £M	Water Quality Disbenefits	Environmental impacts; Construction Disbenefits	Environmental impacts; Operation Disbenefits	Environmental impacts; Operation Benefits
a)	Riverside Groundwater		70	70	N/A	0	Low	0	0
b)	London Basin Groundwater		-	231	N/A	0	0	0	Low
c)	Drayton Reservoir+		600	300	330	Mod	High	Mod	Mod
d)	Redevelopment of Staines Reservoir		-	70	20	0	High	Mod	0
e)	Re-use of Effluent		90'	68	40	Low	0	Low	0
f)	Severn-Thames Transfer *								
	i)	to Drayton Reservoir	400	190	190	Low	High	Mod	0
	ii)	To Down Ampney	200	150-170	120	Low	High	Mod	0
	iii)	To Buscot-400 Ml/d	400	150	160	Mod	High	Mod	0
	iv)	To Buscot - 200 Ml/d	200	120	85	Mod	High	Mod	Low
g)	Anglian Region Transfer*								
	i)	Thame transfer with storage *	100	103	190	Mod	Mod	Mod	0
	ii)	Stort transfer (no storage) - 200 Ml/d	200			Mod	Mod	Low	0
		- 100 Ml/d	100	50	125	Mod	Mod	Low	0
	iii)	Roding Transfer (no storage)	100		125	Mod	Mod	Mod	0
	iv)	Increase in Grafham Water use	100	100	150	Low	Low	Low	Low
h)	Storage with Transfers								
	i)	Waddesdon Reservoir		incl	18	Mod	High	Low	Low
	ii)	Down Ampney Reservoir - 200 Ml/d		incl	15	Mod	Low	Low	Low

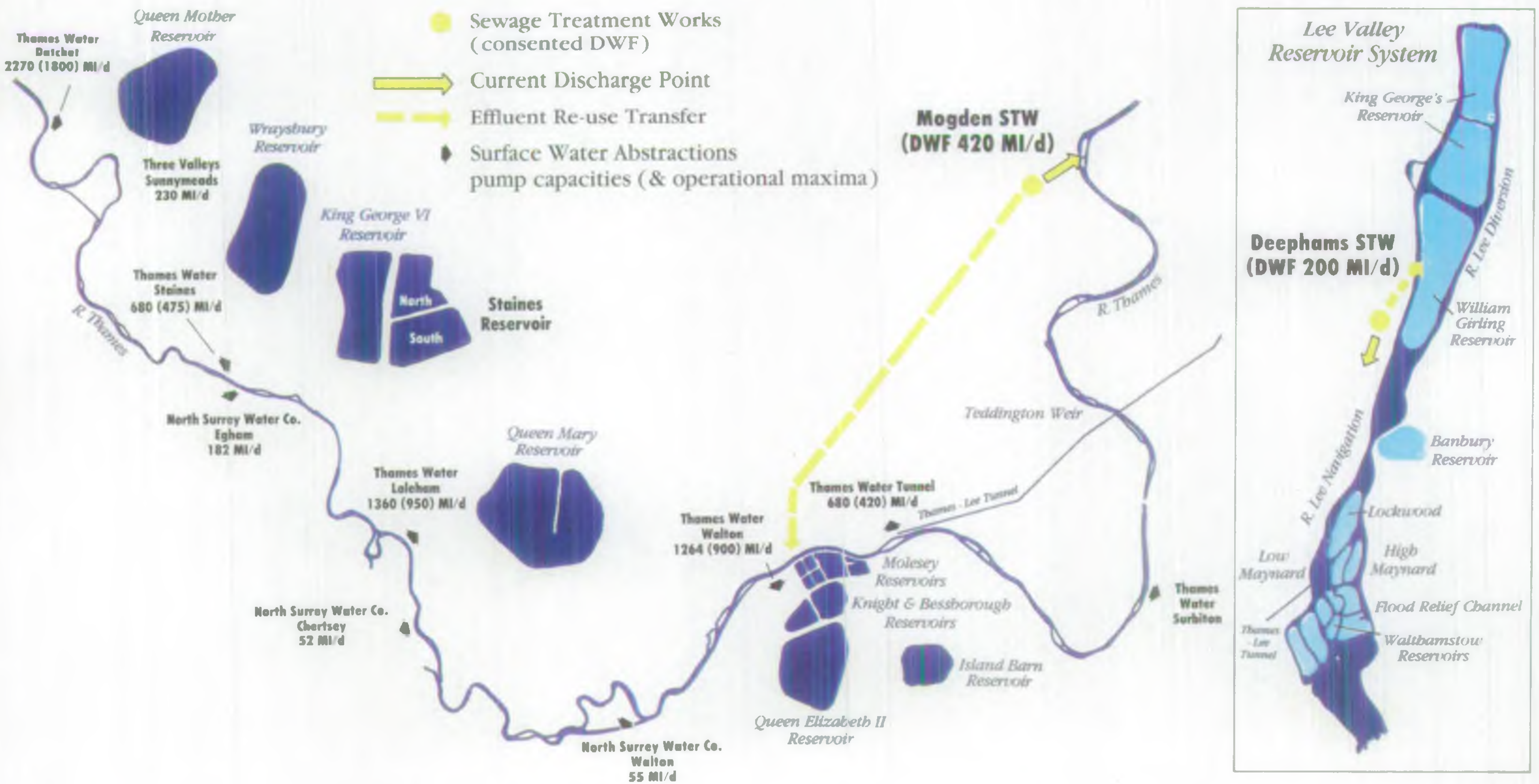
* Excluding engineering costs and regenerating capital cost of M&E plant every 15 years

0 No significant impacts predicted, positive or negative

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

' Potentially 800 Ml/d; only 90 Ml/d required to meet demand deficits

Figure 2. Strategic Surface Options Within The Lower Thames: Effluent Re-use & Staines Redevelopment



4.11 North London Artificial Recharge scheme

An artificial recharge scheme in North London is already partially developed in the Lee Valley; a new scheme currently being developed at Enfield-Haringey could yield up to 90 Ml/d. When fully developed, the schemes will utilise dual purpose recharge and abstraction boreholes. The abstracted water would be discharged to the Lee valley reservoirs, either directly or indirectly via the New River. Recharge will be in the form of low pressure (trickle) injection of off-peak mains water into the unsaturated Chalk/Basal Sand aquifer.

4.12 South London Artificial Recharge scheme

Although Artificial Recharge is being investigated, an alternative scheme could be developed based on decreasing groundwater abstraction and using the London Water Ring Main under 'normal' conditions with abstraction from the naturally recharged aquifer storage during 'dry periods' and the consequent reduced use of the river water feeding the ring main. Investigations are at an early stage and further work is required to confirm the viability of the scheme and quantities available.

4.13 Rising Groundwater

Reduced groundwater abstraction since the 1950's has caused water levels to rise, posing a threat to foundations and tunnels constructed while levels were depressed. Groundwater levels could be controlled by pumping and using the water for supply subject to quality. The practicalities of using such isolated pockets of groundwater, largely within the TWUL area, are currently being investigated.

4.14 Other Artificial Recharge Opportunities

North London and South London are considered the most suitable areas for aquifer management utilising artificial recharge. Earlier work has suggested other areas in East London, North west London and Slough as possibilities. These are long term prospects and further feasibility work is required before deciding whether or not there is potential for development.

4.15 Yields & Constraints

Engineering requirements include about 50 additional borehole sites and linkage to the distribution system. The yields estimated to be available from these new schemes are as follows;

* North London Schemes;	90 Ml/d
* South London Schemes;	60 - 90 Ml/d
* Rising Groundwater in conjunction with the revision of existing licences and full licence take up;	20 - 30 Ml/d

Exact quantities likely to be available have yet to be proven through investigation.
Water quality may become a constraint to the development of the South and Central London schemes due to the leaching out of gypsum and pyrites and the resulting high concentrations of calcium, magnesium, iron and sulphate through the repeated desaturation and saturation of basal sands.

Requirements for additional treatment and blending have yet to be fully evaluated. Depending on these requirements, the yields of such schemes could be significantly higher.

Overall, environmental impacts are limited except for a possibility of derogation of private abstractions and the need to protect spring-fed rivers in South London (both of which can be controlled).

4.2 Groundwater Opportunities Elsewhere in the Region

There are only limited opportunities for new groundwater development outside the extensive confined aquifer of the London Basin and its potential for utilising artificial recharge. The opportunities that do exist are considered below. There are a number of cases where either existing authorised sources cannot achieve licensed quantities or where the 'reliable yield' could be improved by new sourceworks, additional treatment or possibly relocation. These, in addition to improvements in infrastructure between zones (and possibly between companies) could assist in the alleviation of localised shortfalls in resources.

4.21 Thames-side

Development of this type of abstraction from the Chalk in the middle Thames area has recently taken a major advance with the licensing of Gatehampton (70 Ml/d). Pumping tests in recent years have identified yields of at least 10 Ml/d at each of the three additional sources; Remenham, West Marlow and Harpsden. Further sites may also be available in the Reading area. At present the additional yield available in aggregate should be assumed not to exceed 50 Ml/d.

4.22 Lower and Middle Kennet

A number of opportunities, on various timescales, can be considered. In the short term, conjunctive use of the main Newbury sources (Bishops Green, Speen and East Woodhay) could produce limited (approx. 5 Ml/d) additional yield linked to environmental protection through prescribed flows on the Kennet. Looking slightly further ahead to allow for further investigations, disaggregation of the Pangbourne/Theale licence could, if environmentally acceptable, release 10-15 Ml/d of additional resource.

In the medium to long term, further local resources could potentially be made available through the modified use of the West Berkshire Groundwater Scheme, whilst still maintaining its strategic value. Augmentation of the River Kennet could provide additional flow downstream to Fobney, Reading for both supply and environmental purposes. An alternative or extended scheme using the natural characteristics of the confined aquifer could be based upon artificial recharge.

4.23 North Downs

Very limited opportunities exist in this area, largely the Wandle and Hogsmill catchments, because of the need for environmental protection of spring flows. Any development would be approached on a trial basis; an existing temporary licensed abstraction of 5 Ml/d at Chipstead could become permanent and possibly a further additional 5 Ml/d may be available from the Purley area.

4.24 Lower Greensand

The overall level of utilisation of this aquifer appears to be relatively modest. A 3-year research project is planned to start later this year, aimed at improving our understanding of this aquifer. An assessment of further resource development potential particularly by utilising confined areas will be attempted. This is a long term prospect and it is too early to put a yield figure to it.

4.25 Alleviation of Low Flow (ALF) licence reductions

In the context of groundwater development, potential reductions in yield needs to be recognized where cases of low flows attributable to abstractions can be demonstrated. The NRA has already identified six cases which affect the Thames Region (Darent, Ver, Misbourne, Pang, Wey and Letcombe Brook). The following yield reductions relate to catchments where schemes to alleviate low flows have been identified;

Catchment	Scale of Licence Reduction
Ver	15 Ml/d
Misbourne*	8 - 15 Ml/d
Pang	9 Ml/d
Letcombe Brook	Nil
Wey	0 - 5 Ml/d (no preferred option yet)

Further cases are currently under study and discussions are being held with the water companies. These include;

Churn/Ampney Brook	5 - 20 Ml/d
Cherwell	} reliability reduced by imposing
Windrush	} or tightening prescribed flows
Wye*	0 - 10 Ml/d
Gade*	5 - 10 Ml/d
Beane	10 Ml/d
Mimram*	0 - 8 Ml/d

where * indicates that losses may be reduced or avoided by moving abstractions to alternative sites.

Any reductions in yield as a result of these schemes will bring forward the need for new resources or enhanced demand management activities.

4.3 Effluent Re-use

The indirect re-use of effluent is already widely practised within Thames Region by nature of the geography of the R. Thames. This option looks at ways in which more 'managed' and intensive schemes can be developed. The bulk of the potable water consumed in the London area is abstracted from the R. Thames above the tidal limit at Teddington weir and from the non-tidal reaches of the R. Lee. Virtually all this water is brought, after use, to sewage treatment works (STW) which discharge on average some 2400 Ml/d of treated effluent to the tidal R. Thames to be lost to the freshwater system. Additionally treating and diverting a proportion of this effluent upstream for re-use within the freshwater river system could enable significant enhancement of the resources available to London.

A series of tideway STWs were considered. Mogden and Deephams, conveniently placed with respect to reservoirs and water treatment works (WTW), were considered further (see figure 2). Other works such as Beckton and Crossness, both downstream of the Thames Barrier, are relatively more difficult and costly to develop.

Possible 'managed' re-use schemes include:

* supply direct to the London Ring Main;
* supply to WTW and blending with raw water prior to treatment;
* mixing with raw water in a reservoir;
* discharge above Teddington/Molesey weirs below the existing abstractions supporting residual flows and allowing increased abstraction upstream;
* discharge to the River Lee or New River upstream of Lee Valley reservoirs.

The latter, indirect reuse options, appear preferable given the opportunity to blend tertiary treated (Filtration-Ozonation-Aeration) effluent with river or reservoir water. This should provide appropriate opportunities to manage re-use schemes to meet public health requirements. Other potential indirect reuse opportunities are currently being investigated by TWUL and others ie. for non-potable purposes such as irrigation of Golf courses etc.

4.31 Diversion of part of the Mogden STW discharge

At times of low flow, tertiary treated effluent could be transmitted via a 2.0 m tunnel to the Thames below the Walton intake to augment the residual flow in the Molesey-Teddington reach thus allowing an equivalent amount of natural flow to be abstracted upstream to fill the lower Thames reservoirs and increase transfers via the Thames-Lee tunnel.

Reducing flows (of effluent) in this reach of the tideway may have implications for water quality management and the control of saline penetration. Further investigations are required to establish whether this is a feasible option or if there are sound environmental/public health reasons for its rejection at an early stage.

4.32 Diversion of part of Deephams STW discharge

The preferred scheme would be to pipe tertiary treated effluent to one of the Lee Valley reservoirs or alternatively to the R. Lee upstream of the main intakes. NRA understands that both options are under consideration by TWUL. Operation of such schemes would be triggered by reservoir and aquifer storages in London.

4.33 Water Quality & Environmental Issues

Although tertiary treated effluent is likely to be of superior water quality than the receiving waters, there remains some doubt as to whether this level of treatment would be sufficient to handle certain constituents of trade effluents. The removal of one third of Mogden effluent discharged to the tideway could possibly have a beneficial effect on chemical water quality, preliminary water quality modelling suggests dissolved oxygen could increase by 5%. However the biological water quality impacts of such a scheme and the effect of removing flow to the tideway (ie. siltation, saline penetration etc) would need to be fully evaluated.

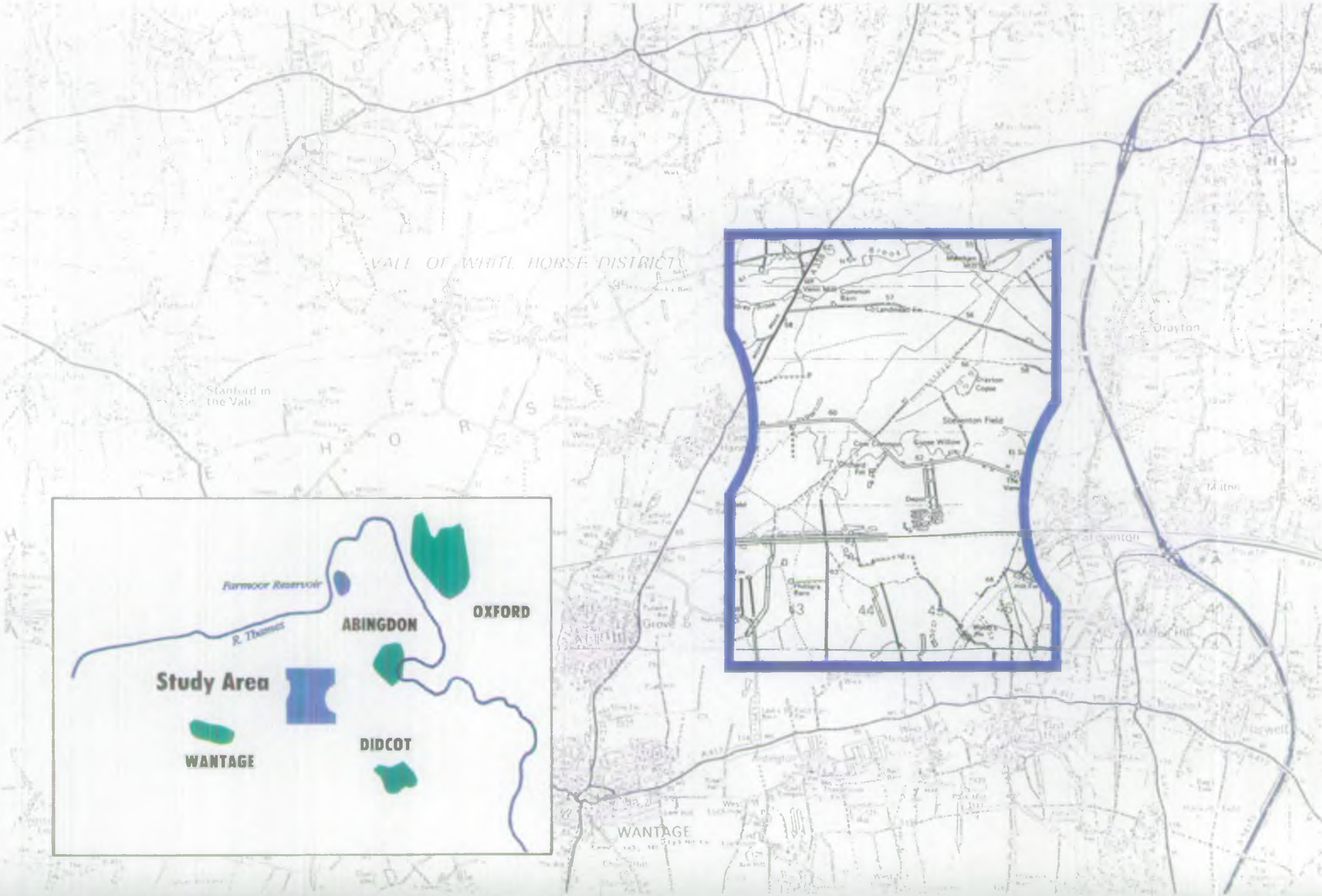
Up to 50% of the dry weather flow (DWF) from the Deephams or Mogden works could be re-used whilst maintaining substantial flows to the tideway, i.e. 50-100 Ml/d from Deephams STW (DWF of 200 Ml/d). Public perception is the major constraint to the development of this resource. As a consequence this option is currently only considered as a long-term development.

4.4 Storage Options

4.41 South West Oxfordshire Reservoir proposal

Reservoir development in Thames Region is heavily conditioned by the following; topology, geology, land use, demography, development planning and environmental impacts. TWUL have identified a site near Abingdon (see figure 3) as best to meet the numerous conditions and constraints of development; this study did not review the choice of site. Reservoir storage up to 150,000 Ml could provide a resource of the order of 300 Ml/d to serve London and the Upper Thames.

Figure 3. South West Oxfordshire Reservoir Proposal



Following selection of a single site, TWUL has carried out a feasibility study which included an intensive geotechnical investigation to determine the engineering suitability of the site for a reservoir development and numerous environmental studies. In February 1993, TWUL formally announced their decision to continue more detailed studies towards the promotion the south-west Oxfordshire reservoir scheme. The scheme proposed could provide storage up to 150,000 Ml/d. Abstraction and augmentation is being considered within the Culham Reach of the River Thames. The scheme is being promoted essentially to meet future demands within the London area and would be used to augment the river at times of low (drought) flow. The scheme could be used, on a lesser but continual basis, to meet future demand growth in the Upper Thames.

Environmental impacts on-site during construction could be significant, although most effects could be ameliorated with appropriate mitigation measures. Construction would require considerable landtake, loss of a number of buildings, noise, dust, vibration and increased traffic movements. Of particular interest to the NRA will be the control of site drainage and effects on surrounding watercourses which will require careful control and monitoring eg. ensuring that suspended sediment loads do not increase in the lower R. Ock during the earth movement phase of construction.

Once constructed, the scheme could have both impacts and benefits to the environment. Various investigations have commenced to establish baseline environmental conditions and identify potential impacts. There will be substantial planning interests: for example, in assessing the visual impact of a scheme with 25m embankments as opposed to the benefits of landscaping; transport and recreation issues. The operation and management of the scheme and location of the intake and outfall will be of particular interest to the NRA in the consideration of licence and consent application by TWUL. A host of key issues will need to be addressed in the lead up to licence, consent and planning applications;

- controlling abstraction and augmentation to avoid harm to the river Thames and its environment;
- establishing an acceptable location and structure for abstraction and augmentation, defining flow constraints or objectives for the river to safeguard the river environment and other users;
- controlling reservoir water quality and augmentation flows to prevent impact on the environmental quality of the river;
- establishing how the scheme would operate in conjunction with existing sources to the benefit of the water environment;
- evaluation of the potential size of the reservoir, and the wide range of local features which may need protection;
- providing appropriate mitigation measures for local environmental impacts;
- identifying local land drainage constraints and addressing any issues which may be raised;
- identifying other potential benefits of such a scheme. For example, to other abstractors from the River Thames, other river uses and the river environment.

In addition, opportunities for environmental enhancement, recreation and conservation will be investigated.

4.42 Redevelopment of Staines reservoirs

The feasibility of enlarging present storage at Staines North and South reservoirs has been considered by TWUL. Timing is critical for this option as a large new resource will need to be operational before the Staines Reservoirs could be taken out of service (for approximately 6 years) and redeveloped.

The scheme would involve deepening the North and South Staines reservoirs (see figure 2) by raising bunds and removing the causeway which separates the two reservoirs in order to create additional storage. Approximately 10000 Ml additional storage could be provided in this way providing an increase in resources to London of 70-150 Ml/d.

The development may require an alteration to the draw-off/fill operations, additional forced aeration/circulation, additional pump capacity and consideration of safety aspects for the local residents.

Construction would bring noise, dust, vibration and traffic movement. The redeveloped reservoir would have a visual impact for residents and visitors with little opportunity for mitigation. A major disadvantage of this scheme is the (temporary) loss of a wildfowl SSSI on the existing reservoir. With appropriate design, however, the redevelopment could provide opportunities for habitat enhancement.

NRA understands that separate studies carried out by TWUL into this option have raised doubts as to the engineering feasibility of raising the existing bunds at Staines requiring the complete redevelopment of the site. If this is so the environmental impact within the Staines urban area is less likely to be accepted then partial redevelopment and the significant extra costs involved would give grounds to reject this option. Evidence of further studies undertaken and the costs and environmental implications will be required to substantiate the rejection of this option.

4.5 Inter-regional Transfer and Storage Options

Options for alternative storage sites have only been considered in this study as part of possible Severn and Anglian transfers (see 4.6 and 4.7) to provide essential storage at times of low flow when water is unlikely to be available for transfer, not as alternative schemes to the south west Oxfordshire reservoir proposal (see 4.41).

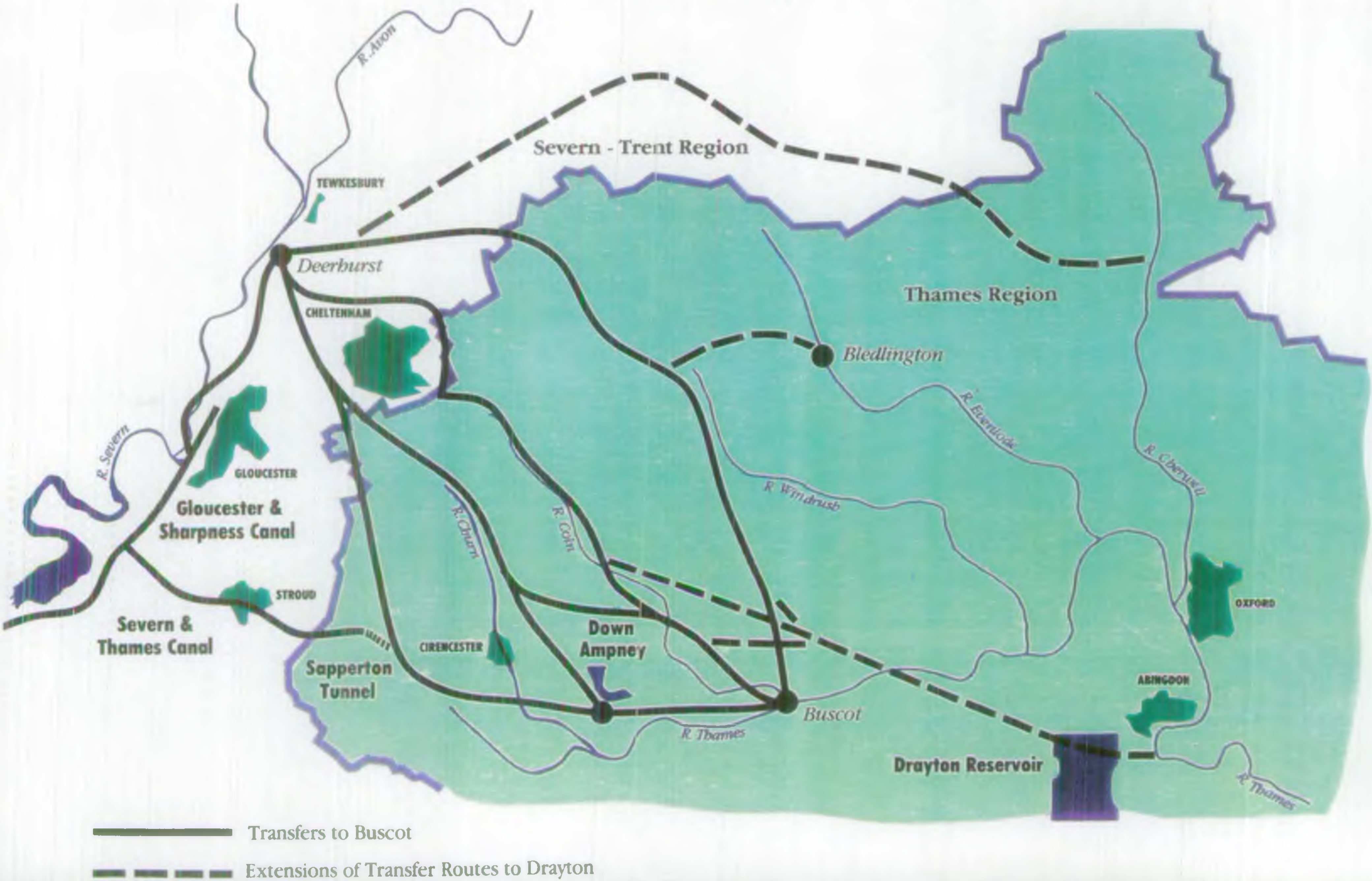
4.51 The use of gravel pits in the Upper Thames

Gravel pits have been suggested in the past as an economic and environmentally acceptable means of providing surface storage as an alternative to large purpose-built reservoirs. Despite the fact that the Upper Thames has many examples of worked-out gravel pits, the prospects of using potential future large gravel workings is preferable to changing the use of existing ones.

Transfers from the Severn to the Thames are likely to require at least 25000 Ml storage for balancing and blending. Gravel pit capacity can be increased by further excavation and providing perimeter embankments. Lining is likely to be required to maintain watertightness. Although many options have been considered the only potential site within existing County Minerals plans with sufficient planned excavation storage capacity is at Down Ampney. Gravel extraction is planned to commence here within the next 10-15 years and the site is ideally placed to receive a transfer from the R. Severn and serve a pipeline to the R. Thames at, for example, Buscot. However, current final restoration policy is to agricultural land because nearby pits have already been utilised by the Cotswold Water Park and a conflict of interest may arise in this case.

One key environmental constraint is the effect such schemes could have on flood capacity and land drainage although the diversion of gravel groundwater flow around sealed pits is considered not to create a significant impact. The constructional impacts are relatively less than other reservoir developments. Encouragingly, Down Ampney has no identified conservation constraints and is located outside the floodplain.

Figure 4. Severn-Thames Transfer Options



The operation and use of gravel pits in conjunction with transfer schemes is discussed under 4.6 below.

4.52 Reservoir at Waddesdon

This site was identified by the Water Resources Board (WRB) in 1960 and 70's. This review has considered appreciably smaller storage volumes of the order of 30000 Ml as a component of the Anglian-Thames transfer.

The Waddesdon site, a shallow valley west of Aylesbury, would require the construction of a 17m high embankment (1200m long) and a 5m high saddle dam (600m long). There would be considerable environmental impact; the loss of class 3 agricultural land, inundation of 7 farmsteads, loss of footpaths etc. Indeed the construction impacts could be more significant than the south west Oxfordshire reservoir because of the topography and quality of existing countryside. English Heritage would be concerned at the potential impact on the setting and landscape of Waddesdon Manor.

4.6 Transfers from R. Severn to Thames

This option has attracted most attention and study in the past as key elements of the Water Resources Board and Central Water Planning Unit studies. Previous studies assumed storage to support transfers in the donor catchments, i.e. Severn and Wye; there is however, no longer a need for large scale river regulating storage in the Severn area, with future regional needs being met from the further development of the Shropshire groundwater scheme. The provision of storage in the Thames catchment would:

* obviate the need for remote storage and associated works, i.e. Craig Goch development;
* eliminate further regulation losses on the Severn;
* provide opportunity for blending with Thames-derived water overcoming most water quality and environmental concerns;
* have management advantages for promotion, financing and operational control.

This study has adapted the CWPU recommended intake location, discharge point, routing and means of transmission within their investigation.

4.61 Route options

Recommended schemes involve abstraction from the R. Severn at Deerhurst (see figure 4) after which it is transferred via pipeline and discharged to either the Thames at Buscot or directly into a reservoir, i.e. south west Oxfordshire reservoir. The abstraction itself will have a limited impact on the Severn catchment given a residual flow of the order of 2500-4000 Ml/d to the estuary to safeguard Bristol Water plc, British Waterways (Gloucester-Sharpness Canal) and the estuarine environment. The preferred transfer route follows partially the CWPU route 4 traversing north of Cheltenham crossing the Cotswolds and joining the Thames via the Cotswold Canal, Churn or Coln Valleys.

The wider use of canals, for example the Oxford or Grand Union Canal, as transfer routes has previously been rejected by WRB, CWPU and Consultants. Recent investigations by British Waterways appears to suggest that canals can be engineered to carry flows of 200-300 Ml/d without undue impact on navigation or other canal uses. NRA and British Waterways are currently undertaking joint studies to investigate their feasibility further and this work is due to report on July 1993.

4.62 **Discharge location options**

Options for the point of discharge include:

* discharge to the R. Thames for abstraction in the Lower Thames;
* discharge to the R. Thames, Culham Reach, for the south west Oxfordshire reservoir abstraction;
* discharge directly to south west Oxfordshire Reservoir;
* discharge directly into Upper Thames gravel pit storage;
* direct supply to Swindon and Upper Thames (thus reducing transfer costs).

The scheme would require a low lift pumping station at Deerhurst; 3 days bankside storage for sedimentation, mixing and emergency provision; high lift pumping station in the Cotswolds, River Thames bankside storage and a discharge structure.

4.63 **Environmental issues**

There remain a number of environmental concerns regarding the potential impact of river to river transfers. These include:

- the implications of discharging lowland Severn water (which would include treated effluent from Midland urban and industrial areas) into the Upper Thames. To date there have been no pollution incidents requiring closure of intakes on the lower Severn. Chemical analyses have shown that, in terms of the general water quality determinands the two river waters have similar quality; more important considerations appear to be:

    * concentrations of soluble reactive phosphates which may affect the stability of mineral salts;
    * pesticides and herbicides;
    * detergents.

- the increased risk of eutrophication and algal blooms. Although the two rivers have similar algal flora, the introduction of lower Severn water to the Thames at certain times of year could enhance periods of maximum population levels and extend zones of maximum density with consequent quality problems. However, some algal control is achieveable through adequate operational measures.

- the potential affects on aquatic biology in particular fisheries. This includes flow effects on receiving waters as well as transfers of disease. To a certain extent, the affects of flow and "wash-out" of fry or macrophytes could be controlled by establishing river flow objectives which protect the river at key periods. The potential transfer of fish diseases has yet to be fully understood, although data from the Severn Trent and Thames regions appears to show broadly similar diseases being prevalent in both catchments.

- affects of changing water quality on the homing response of migratory fish.

- archaeological constraints on development timescales and pipeline routes. Any development of this option would require an archaeologist to be a full time member of the construction team as there is likely to be significant potential to encounter buried sites during construction which will require identification and protection. This could also slow down development timescales.

Whilst these concerns remain to be fully investigated, there could also be some benefit to the environment if managed effectively, In particular, maintaining flows in dry periods (where practicable) would be beneficial to aquatic fauna, fisheries and general recreational use.

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REGIONAL TECHNICAL MANAGER

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National Rivers Authority
Thames Region

M E M O R A N D U M

TECHNICAL DEPARTMENT

DATE: 25 June 1993

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Tel: 0734 535390

TO: See Circulation List

FROM: Dr Brian Arkell,
Principal Planner, Water Resources

REF: WRS E6.1

**WATER RESOURCES STRATEGY SCHEME DEVELOPMENT OPTIONS
TECHNICAL OVERVIEW**

Please find enclosed a copy of the above report.

This report was first circulated to members of the NRA Thames Region Water Resources Consultative Forum, in draft form and a number of amendments were subsequently made towards this final document.

This is the first in a series of reports leading to a Regional Water Resources Strategy. This strategy will undergo a full public consultation exercise later this year. We do not currently anticipate the release of this document into the public domain.

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NRA Thames Region

Water Resources Strategic Schemes Development Options
Technical Overview

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Nevertheless, as a result of the water quality concerns in particular, a transfer via reservoir storage would be a preferable option.

Transfer rates up to 400 Ml/d are being considered. With the 400 Ml/d transfer rate, flows at Buscot would exceed or approach current monthly maxima for much of the year. Any impact of such transfers to aquatic biology depends not only on the magnitude but also the transfer frequency and water quality from the Severn. The rate of release to the river is also critical and should not exceed seasonal flood discharge capacity.

4.64 Reallocation of Lake Vrynwy

The NRA National Water Resources Strategy is investigating alternative resources to augment River Severn flows during drought periods. For example, reservoir storage currently used to supply the NRA North-West Region; reallocation of sources could support augmentation to the River Severn guaranteeing a minimum transfer quantity to the Thames Region. Further studies of engineering, environment and cost implications of such schemes are currently underway.

4.7 Anglian-Thames transfer

Over recent years, the water and environmental quality of the R. Trent has been improved to such an extent that the Trent is now being viewed as a potential resource by NRA Anglian Region in particular. In-river residual flow requirements of the order of 1750 to 2500 Ml/d will constrain resource availability ~~largely to winter only~~, unless supported by storage either regulating the Trent or within Anglian Region. This is under review elsewhere in the NRA and is not discussed here.

Anglian Region already operates schemes to support Essex Water Company; the company is also reliant on resources from Thames Region. As part of a study of strategic options for the Anglian Region, consultants have been asked to identify ways in which resources may be released to, or made available to, Thames Region.

The proposals being considered are based on a series of southward river basin transfers from the development of R. Trent resources (see figure 5). Any transfer to Thames Region would have been diluted and blended en route several times over. The most significant feature of the scheme is the scale of discharge compared to the receiving rivers, i.e. Thame, Stort and Roding. Transfers of up to 600 Ml/d are being considered for the whole scheme up to 200 Ml/d of which could be made available to Thames Region.

4.7.1 Possible Transfer Options

Four potential routes could provide benefit to Thames Region:

a) **Transfer to R. Thame.**

The transfer of Great Ouse river water (100 Ml/d) via by pipeline to a reservoir at Waddesdon for augmentation of the R. Thame (200 Ml/d maximum). A reservoir at Waddesdon reservoir could also be used for direct supply to Aylesbury and surrounds.

The engineering works required are discussed in section 4.52
A maximum discharge of 200 Ml/d from the reservoir would result in a residual flow above the monthly maximum during July and September and a doubling of mean flow in summer and autumn months. The extra flow may be beneficial in relieving the excessive weed growth and siltation which occurs in the R. Thame during low flows.

b) **Grafham to Three Valleys Water Services (3VWS)**

This option involves additional use of Grafham storage to supply treated water to 3VWS (assumed 100 Ml/d resource value). The works required for this scheme include an expansion of the Great Ouse pumping station, transfer pipeline to Grafham Water, additional pumping station and treatment plant at Grafham and an additional 1.0m diameter pipeline to Luton (100 Ml/d).

The constructional impacts are minimal since the scheme involves a replication of existing facilities. The scheme may incur greater and more frequent level fluctuations of Grafham Water and a negative visual impact of a muddy foreshore at low water level which could impact on recreational activities such as sailing and would need further study.

c) **Transfer to Roding and Stort via Ely/Ouse-Essex system**

Transfer to the Thames Region of approximately 200 Ml/d via the Ely/Ouse-Essex/western extension of the Stour to Blackwater transfer scheme could supply Essex Water Company (EWC), TWUL and possibly 3VWS. A number of options have been identified

* Discharge (200 Ml/d) to the R. Stort for abstraction by TWUL/3VWS in the Lee valley;
* Discharge (100 Ml/d) to R. Roding for abstraction by EWC at Chigwell and thereby relieving the bulk supply commitment from TWUL;
* A transfer direct to EWC Chigwell WTW meeting future company needs as well as relieving TWUL bulk supply commitment.

i) Discharge to the R. Stort

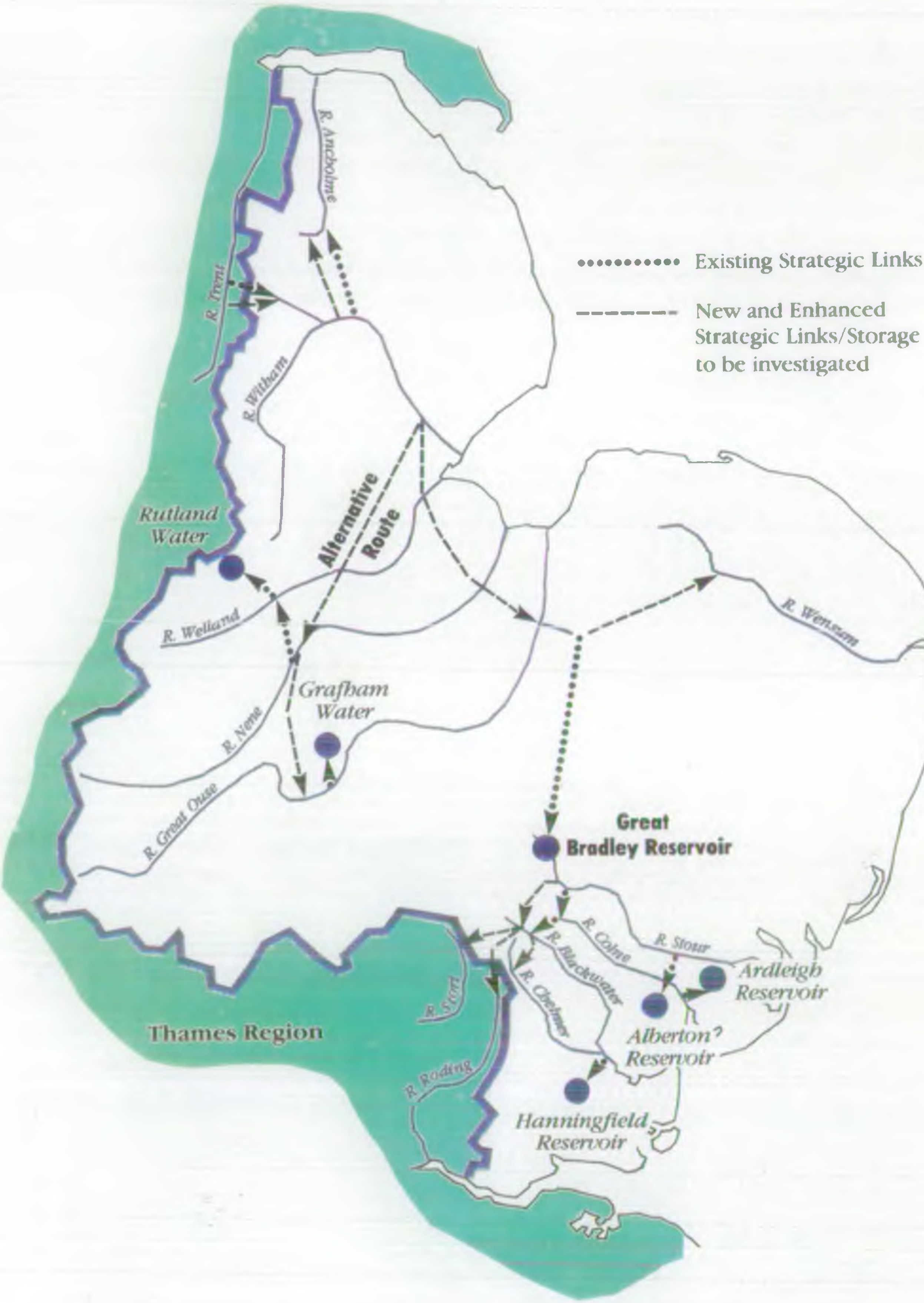
This scheme would require an intake and pumping station at Great Barfield, a 28Km pipeline to the R. Stort at Sawbridgeworth, discharge structure and alterations to navigation structures.

Pipelines are likely to run through a number of special landscape areas such as the Stour Valley, intensively farmed grade 2 land and the Stort Valley Nature Conservation zone (Hatfield Forest SSSI). The R. Stort is also an EC designated Cyprinid fishery. The upper Stort upstream of Bishops Stortford does not have the channel capacity to support 100 Ml/d. Discharge of an additional 100 Ml/d discharged to the river downstream of Bishops Stortford would increase flows to exceed monthly maxima for 7 months of the year which is likely to cause considerable environmental impact without significant channel engineering. It was concluded that a supply to EWC would be better effected via an alternative option. Considering the scale of impact or mitigating works, this option was not pursued further.

ii) Roding transfer sub-option

Proposed pipelines would run through two special landscape areas and grade 2 agricultural land; there are also several SSSIs within the 10 Km pipeline corridor which would require appropriate mitigation works and reinstatement. In addition, the works are likely to expose archaeological remains. Significant channel modifications would be necessary downstream of High Ongar in order to accept the increased flows to the R. Roding which could have implications for fisheries (EC designated Cyprinid fishing) and the river environment in general. Alternatively, extending a pipeline direct to EWC-Chigwell WTW would avoid these impacts and may be a preferred scheme on environmental rather than on economic grounds.

Figure 5. Anglian Region Transfer Options



d) Supply from Great Bradley (NRA-Anglian) and the Shrubhill (EWC) reservoir proposals

These schemes would be based on a direct supply of treated water (200 Ml/d) to 3VWS, EWC and TWUL from a new reservoir at one of two sites being considered, Great Bradley or Shrubhill. The supply to EWC could potentially release the present 91 Ml/d bulk transfer from TWUL. The feasibility of Great Bradley is currently under study by NRA Anglian Region, in addition to an alternative scheme being proposed by EWC at Shrubhill near the Cambridgeshire-Norfolk border. Either scheme is likely to be required to maintain reliability of a Trent-based transfer scheme and a comparison of impacts and benefits of either scheme will be undertaken over the next two years.

Great Bradley has the benefit of being an impoundment requiring only a single bund and, therefore, significantly lower cost that the fully bunded scheme proposed at Shrubhill. Full environmental assessments have yet to be undertaken at each site.

However, schemes based on inter-regional water transfer, as described above, are relatively inflexible when compared to intra-regional options.

5.0 MAJOR COMPONENTS OF A STRATEGY

This report summarises the range of engineering options considered towards meeting future demands within Thames Region. Demand management options will be considered in a subsequent report. From the foregoing, the NRA would envisage a strategy made up of some of the following components:

- ongoing and more intensive effort in demand management: including a full evaluation of the costs and benefits of domestic metering;
- ongoing optimisation of existing licensed sources;
- ongoing development of London Basin groundwater options, artificial recharge and rising groundwater in Central London;
- ongoing investigation and development of riverside groundwater sources in the middle Thames area and middle Kennet around Newbury;
- development of surface water storage (ie. south west Oxfordshire reservoir);
- development of schemes for 'managed' re-use of treated sewage effluent (Deephams and Mogden);
- development of inter-regional transfer schemes.

The 'managed' re-use of sewage effluent currently discharged to the Tideway from the Greater London area appears to be a practical option both in terms of the relative ease of engineering development and cost. Some environmental issues remain to be resolved particularly with regard to the re-use of effluent from the Mogden works and its effect on the Tideway. We understand that the extent to which public perception may be an issue against promotion of these schemes is being investigated by TWUL. Drinking water safety, of course, must be assured.

The feasibility of a new regulating and direct supply reservoir in the Abingdon area is currently being investigated by TWUL. This scheme could provide a number of benefits to regional water resources management; in particular, conjunctive use with existing sources and the opportunity for water to be made available to other abstractors via augmentation or bulk supply. Environmental disturbance will be controlled during construction. Any potential environmental effects of scheme operation could be minimised or mitigated through appropriate regulation. Key concerns to NRA include the management of stored water quality and the management of abstraction and augmentation (especially water quality) to avoid harm to the R. Thames and its environment.

Options for transferring water from the Severn to the Thames seem at this stage likely to figure later in a strategy because of the need for storage within the Thames Region to safeguard water quality and resource reliability unless reallocation of Severn regulation storage (Wales) becomes feasible. The successful promotion of the south west Oxfordshire reservoir (or an alternative scheme) seems a logical step prior to the development of a Severn to Thames transfer scheme without storage elsewhere. Alternative storage schemes are being evaluated within the context of a Severn-Thames transfer in order to assess potentially competing schemes or alternatives should the promotion of the south west Oxfordshire reservoir fail. NRA Thames Region have appointed consultants to undertaken a Severn-Thames transfer feasibility study to assess the engineering, environmental and economic feasibility of such schemes. Transfers via the Upper Thames tributaries remain unacceptable due to the environmental impacts on receiving waters. At this stage, favoured options include transfers via re-instated canal routes or via pipeline through reservoir storage to the River Thames. Water and environmental quality impacts have yet to be fully evaluated but could be significantly mitigated by blending with stored Thames water.

On the basis of capital costs alone, schemes to transfer water into the region via the Anglian rivers appear very competitive compared to some regional solutions, for example the south west Oxfordshire reservoir scheme. However, there are a number of disadvantages in reliance on these schemes:

- operating costs are likely to be very high compared to many other schemes;
- as currently envisaged, the schemes could have significant environmental impact on receiving water courses which would be unacceptable to the NRA;
- the benefits of regulation of the R. Thames, including the opportunity for abstraction and return prior to the London demand centre, will be lost unless alternative reservoir sites can be promoted as part of an Anglian Transfer Strategy. The extent to which other demands become an issue will need further detailed evaluation.
- the politics of advancing a strategy remote from this region whilst certain 'internal' options remain to be developed could pose difficulties.

In perspective, there are a number of issues to be considered in assessing transfer options as competitors against the south west Oxfordshire reservoir proposal. Initial proposals suggest that it could provide some 300 Ml/d resource value which could be made available region wide (in this context, to Swindon, Oxford and all abstractors downstream of the scheme to London - provided upstream effluent is returned via the Thames). In so doing, opportunities would be provided for conjunctive use with, and better management of, existing resources. Transfers via Anglian Region could only satisfy future demands of parts of Three Valleys Water Services and TWUL London unless made with storage provision to the west of Thames Region, ie. on the R. Thame. The overall costs and environmental impact of this combined option make it unfavourable. In meeting future growth in London alone, NRA Thames Region believes the Anglian options merit further study. On the other hand, transfers via the R. Severn, although providing the regional resource element referred to above, would only provide two thirds of the yield estimated to be available from the south west Oxfordshire reservoir. The remainder would have to be made up from additional transfers via Anglian Region. The combined cost of such an option is only marginally less than that of the south west Oxfordshire reservoir, yet there remain significant environmental issues. Neither transfer option would provide full scope for conjunctive use with existing abstractions to reduce their impact during key drought periods. Whether, on balance, given a full regional or strategic view, the south west Oxfordshire reservoir scheme provides sufficient benefits in addition to meeting envisaged future public water supply needs will require future assessment.

6.0 SUMMARY AND FURTHER INVESTIGATIONS

- Schemes currently under investigation/development within the London area should be pursued with vigour to make up for the existing deficit in resources.

- 'Managed' re-use of sewage effluent is feasible in engineering terms but there remain concerns as to the public acceptability of the practice on a frequent basis. Further detailed investigations, including the use of 'greywater', are required to satisfy environmental interests, consent and drinking water requirements.

- Redevelopment of existing reservoirs may not be feasible due to engineering, environmental and cost constraints.

- No single scheme could provide as large a yield as the TWUL south west Oxfordshire reservoir proposal (300 Ml/d) or provide the strategic water resource benefit required of any new strategy. A new regulating reservoir near Abingdon could provide significant regional benefit to water resources management provided concerns regarding water quality and quantity management can be addressed. Detailed environmental studies on the proposed site and the River Thames should continue to ensure a satisfactory scheme can be promoted.

- Transfers from the Anglian Region (up to 200 Ml/d) could provide a very economic alternative for resources solely to London. This option would only be practical if demands elsewhere in the Thames region were not realised (or if an enhanced level of demand management was applied across the region) and if availability from the Trent can be proved. Anglian Region transfers should be examined further to:

    - evaluate the costs and benefits of transferring more water into the Essex Water Company area to meet future growth and to relieve the existing bulk supply commitment from TWUL;

    - to identify alternative routes of transfer to Thames Region demand centres which are operationally practical and environmentally sound.

- Transfers from the Severn to the Thames (up to 400 Ml/d) would only be viable if supported by storage within the Thames Region to provide security of quality and yield. Options previously studied which discharged to the Upper Thames tributaries are unacceptable on environmental grounds.

- Water quality and environmental impact remain concerns in terms of river to river transfers. Separate studies have been identified to assess the extent of any impact.

Appendix C lists the further investigations which have been identified to date. The readers attention is drawn to this list, which indicates issues on which NRA will need co-operation.

7.0 REPORTS TO FOLLOW

- Demands for Water: Forecasts of need within Thames Region and an assessment of sensitivity to demand management and leakage control.

- Thames Region Water Resources Development Strategy: an assessment of demands, resources and need for new water resources management schemes.

APPENDICES

Appendix A Environmental Impacts

CONSTRUCTION	OPERATION
Riverside Groundwater	
1-2 month visual effect during excavation & building (pipelines, pump housing & chlorination facilities, access) Need for satisfactory restoration following pipeline installation. Impact on views from riverside footpaths Works close to river will have a strong potential for archaeological remains	No SSSIs in vicinity May effect wetland sites & groundwater fed surface watercourses - need special provision to protect these & the ecology they contain
London Basin Groundwater	
No significant impacts of construction within an existing built environment Limited potential for minor archaeological disturbance	Positive impact of stabilising groundwater levels in London reducing the threat to underground services Abstraction will not effect wetland sites in London area or peripheral spring fed sources outside the London Basin
Abingdon Reservoir	
Considerable impacts; noise, dust, vibration & traffic movements in close proximity to Drayton & Steventon Significant impact through major landtake of grade 3/4 agricultural land Loss of a number of dwellings; relocation Creation of new access routes/road diversion Significant negative visual impact; lessened by landscaping, revegetation & flatness of surrounding countryside If not managed correctly construction can produce potentially harmful effluents; oil, particulate input (high suspended solids effect macroinvertebrates & macrophytes) Temporary impacts of pipeline construction between Thames & the Reservoir. Local drainage disrupted (can be mitigated), watercourse diversion Site of this size likely to yield archaeological features; setting of Venn Mill (listed building) may be effected	No planning designations existing on site Emergency planning for impoundment failure & emergency drawdown (flood hazard) Pressure for recreation related development; sailing, canoeing etc. Area of limited nature conservation value, reservoir will have no direct impact on designated/protected site. Wildlife in small semi-natural area ie near watercourses, damp grassland (along railway) & small woodlands; potential for creation of additional habitat around reservoir perimeter Conservation gain; reservoirs are often designated wildfowl SSSIs, potential to become important wetland, operation may result in reduced groundwater abstraction in the Cotswolds & help alleviate low flows May reduce winter flooding extent; adverse effects on downstream nature conservation sites Operation will slightly increase flow in the summer months; potential benefit Changes in water quality arising from storage & augmentation; eutrophication & algal blooms Changes in flow, temperature & substrate regime due to augmentation may alter the composition & abundance of benthic invertebrates & fish Increased sedimentation may result; gravel siltation detrimental to Salmonids Intake requires structures to prevent fish from entering reservoir
Redevelopment of Staines Reservoirs	
Noise, dust, vibration & traffic movement (export of aggregates off-site) Severe temporary impact due to bund construction Reservoir drained eliminating recreational use temporarily Loss of SSSI (Wildfowl); due to reservoir draining	Emergency planning Severe visual impact of the bunds - limited screening opportunities Additional reservoir management measures to meet increased depth & capacity Longer term impact if re-creation of habitats proves difficult on refilling; potential for creating wider range of habitats through positive design measures

CONSTRUCTION	OPERATION
Effluent Re-use	
Tunnel construction Temporary visual impact (not significant) Potential for archaeological disturbance at the riverside	Limited & difficult to quantify environmental impacts; likely to be accomodated within existing works Main issues; water quality (variability) & public acceptability Potential problem of STW failure & closure (emergency contingency planning required) Discharge of treated effluent into William Girling & King George V reservoirs is not expected to effect the Ornithological (SSSI) habitat; potential impact on recreation/amenity
Severn-Thames transfer - Gravel Pit Storage	
Less significant than other reservoir developments as works within existing void areas Planning issue; identification & designation of storage locations Upper Thames proposed as an 'Environmentally Sensitive Area' - not likely to alter the policy context of this option Bunding - visual & landscape effects Loss of floodplain capacity - problem if bunding above ground required in sites located on the floodplain Restoration to water looked upon as a positive impact of mineral extraction. No significant archaeological impacts No SSSIs or LNRs within Down Ampney area	Groundwater flow is unlikely to be effected if the gravel pits are lined. Recreational benefits Potential disruption to aquatic biota due to altered flow regime; coarse fish, invertebrate drift, scouring of macrophytes etc. Nature Conservation opportunities; negative influence of abstractions & water level fluctuations Problems of eutrophication & algal rich discharges
Severn-Thames transfer	
Traffic, new access requirements & site related impacts Loss of 40 ha of (good) agricultural land at Deerhurst & Buscot Considerable landtake for treatment facilities, bankside storage etc Pipeline & tunnel; severe visual impact in Cotswolds AONB - public protest likely; impact on agriculture, footpaths, recreational & road areas Requires restoration works following pipeline laying Disposal of soil from tunnel activities Broad route corridors likely to be rich in archaeological & historical remains Local disturbance of drainage system; can be mitigated Changes in hydrology, soil structure, wetlands Possible loss or fragmentation of SSSI habitats (pipeline avoidance) Temporary disturbance of animal communities ie. Badgers & Great Crested Newts Direct transfer to the Drayton site - preferable on lanscape, visual, ecology & quality management grounds.	Possible increased frequency of farmland inundation & rising water table due to higher levels in Thames - opportunity for nature conservation gains to wetlands & water meadows Significant impacts arise from permanent installations, location & design critical ie. intake & discharge Impacts on aquatic biology depend on magnitude & frequency of transfer volume, velocity & water chemistry; - velocities critical to some species ie. carp & bream; therefore fish population may change as a result - large velocities sweep juveniles away - temperature effects ie. life cycles & growth rates - increased shifting of bed material effecting invertebrates Positive impact; maintaining flow in dry weather periods Angling is the only recreational activity affected; riverside infrastructure at Buscot & Deerhurst may give rise to severe & long term impact to recreational use there Chemical impacts; Thames has higher alkalinity & hardness but lower Chlorine & suspended solids content than the Lower Severn (soft waters transferred into hard waters). Catchment Quality control issues also. Changes in the water quality alter homing responses of upstream migratory Salmonids Water transferred from the lower end of a river to the upstream end of another - increases the retention time of planktonic algae. Possible increased likelihood of blooms. However, lower Thames & lower Severn have similar algal flora. Biological differences ie. diseases & parasites between Thames and Severn diminished because of canal connections.

CONSTRUCTION	OPERATION
Anglian Transfer - Thame includ. Waddesdon Reservoir	*Broad impacts identified within the Drayton reservoir & Severn-Thames transfer options are equally applicable here; however the chief difference is the smaller scale of the receiving rivers*
Route passes through & reservoir lies within area of Attractive Landscape (BUCKS structure plan) Severe visual impact from surrounding countryside & Waddesdon Manor (National Trust) Loss of 6 km² Grade 3 agricultural land 7 farmsteads would require relocation Need for improved access through sensitive surroundings Pipeline construction; temporary impacts -greater than at Drayton as a larger amount of material may have to be imported for construction No SSSIs in Reservoir area; number of SSSIs within defined 10km corridor for pipeline Loss of several footpaths; can be mitigated	Visual impact of a prominent water body with 17m high embankments Water based recreational facilities; positive impact Aquatic biology - impacts from increased flow; fish stock displacement, water quality changes, invertebrate drift, scouring of macrophytes, disruption of spawning beds etc. R. Thames is an EC designated Cyprinid fishery (to Brookhouse Brook) Benefits; improved summer flows & therefore reduced siltation Aquatic impacts on the Thame are likely to be more significant than on the Thames due to the lesser ability of the small river to accomodate change
Anglian Transfer - Grafham Increase	
	Potentially significant impacts on the very intensive recreational use at Grafham Reservoir due to level fluctuation
Anglian Transfer - Roding Transfer	
Land is uniformly Grade 2 - good quality; no major landtake is anticipated Several SSSIs in 10km pipeline corridor & should be avoided Pipeline will pass through several Special Landscape areas; requires careful design	Transfers at 100 Ml/d will represent a 10 fold increase in the Roding discharge at Ongar; significant impacts for fisheries & other aquatic biota Interbasin transfers may lead to a deterioration in water quality ie. Trent supported water is class 2 & Roding is Class 1b - requires careful management Roding is an EC designated Cyprinid fishery.
Anglian Transfer - Stort-Lee transfer	
Pipeline passes through a number of Special landscape Areas; requires careful routing to avoid Hatfield forest. There are several SSSIs in the 10 km pipeline corridor (to be avoided). Land classification uniformly Grade 2 - Good quality & under intensive arable cultivation Major negative impact if 'channel improvements' were to take place on Stort & Lee rivers without environmental enhancement ie. large stretches of river downstream of Bishops Stortford impacted already due to canalisation	Minor benefit to Lee Valley park through improved flows in summer. 100 ML/d transfer rates would result in max. monthly flows being exceeded 7 months of the year; significant impacts on fisheries & aquatic biota would result A number of stretches of the Stort are EC designated Cyprinid fisheries.

Generally;
R. Trent raw water quality possibly improved due to basin transfer dilution, blending and interaction before reaching Thames region.

Careful evaluation of archaelogical impact necessary.

Appendix B Engineering Elements

DEVELOPMENT OPTION	ITEM	SIZE
ABINGDON RESERVOIR	Reservoir Tunnel Pumps	100 Mm3 2.5m dia x 4000m 600 Ml/d 3125 Kw installed
STAINES RESERVOIR REDEVELOPMENT	Storage Embankments raised Pumps	10Mm3 increase Northern reservoir by 3m & Southern reservoir by 6m 450 Kw
EFFLUENT REUSE (Mogden)	Sand filters Effluent pumps Ozoniser Tunnel Transfer pumps	90 Ml/d capacity 90 Ml/d, 80 Kw 90 Ml/d capacity 2000m dia x 6500m 90 Ml/d, 80 Kw installed
EFFLUENT REUSE (Deephams)	Sand filters Effluent pumps Ozoniser Transmission Main Transfer pumps	50 Ml/d capacity 50 Ml/d, 45 Kw 50 Ml/d 70mm dia, L < 1000m 50 Ml/d, 130 Kw
SEVERN-THAMES TRANSFER	Deerhurst Intake Low lift Pumps Bankside Storage (Severn) High Lift Pumps (2 stations) Transmission Bankside Storage (Thames) Pumps to Drayton	400 Ml/d 400 Ml/d, 1040 Kw 1.2 Mm3 400 Ml/d, 970 Kw 2000mm, 53K-76Km 1.2 Mm3 400 Ml/d, 2100 Kw
ANGLIA - THAME, STORT TRENT - THAME	Trent Intake Trent-Witham Transmission Witham-Wansford Transmission Witham Pumps Wansford-Gt Ouse Transmission Wansford pumps Gt Ouse - Waddesdon Reservoir Gt Ouse Pumps (2 stations) Waddesdon Dam	700 Ml/d 2400mm dia, L= 10Km 2400m dia, L= 70 Km 700 Ml/d, 13400 Kw 2200mm dia, L= 40Km 600 Ml/d, 9400 Kw 2000mm dia, L= 73 Km 100 Ml/d, 1750 kW 17m high, 35 Mm3 storage
DENVER-STORT	Kennett Pumps Kennett-Kirtling Green transmission Stour improvement Wixoe Pumps Wixoe-Gt Sampford (Pant) Pant (Gt Bardfield)-Stort Gt Bardfield Pumps	200 Ml/d, 3700 kW 1400mm dia, L=14km 11km 200 Ml/d, 2400 kW 1400mm dia, L=10km 1000-1400mm dia, L=28 km 100-200 Ml/d, 2000-2300 kW
GRAFHAM-LUTON	Grafham-Luton Grafham pumps	1000m dia, L=45km 100 Ml/d, 2000 kW
DENVER-STORT/RODING	Kennett Pumps Kennett-Kirtling Green transmission Stour improvement Wixoe Pumps Wixoe-Gt Sampford (Pant) Gt Bardfield-high Roding Gt Bardfield pumps High Roding-Sawbridgeworth High Roding- Longfordbridge (Roding)	200 Ml/d, 3700 kW 1400mm dia, L=14km 11km 200 Ml/d, 2400 kW 1400mm dia, L=10km 1400mm dia, L=15 km 200Ml/d, 2300 kW 1000mm dia, L= 13000m 1000 mm dia, L= 17 km

APPENDIX C

LIST OF FURTHER INVESTIGATIONS

7.1 London Groundwater Development

- Ongoing investigation and development.
- Further work (in conjunction with TWUL) to evaluate how the schemes could be operated conjunctively with existing resources.

7.2 Riverside Groundwater Development

- Ongoing investigation and development.
- Further studies to evaluate abstraction potential and maintenance of environmentally acceptable flows in the Rivers Thames and Kennet.

7.3 Abingdon Reservoir

- Ongoing investigation and evaluation of environmental baseline data.
- Definition of environmentally acceptable flow regimes and operating requirements for abstraction and augmentation.
- Evaluation of reservoir water quality management regimes and river quality management.
- Evaluation of scheme operation in conjunction with existing abstractions to achieve environmental benefit.
- Identification of constraints on structural design and mitigation of potential effects of construction and/or operation.
- Identification of other beneficiaries (other water companies, industry, agriculture and the water environment).

7.4 Effluent Re-Use

- Establish environmental requirements of schemes which may discharge to controlled waters.
- Evaluation of the potential impacts and benefits of transferring treated effluent to the lower reaches of the freshwater River Thames, including the effects of increased saline penetration, and possible effects of siltation on the activities of the Port of London Authority (PLA).
- Evaluation of the potential effects and benefits of using Deephams STW effluent. In particular, the effect on flow and water quality of existing receiving waters (Salmon Brook and River Lee).
- Establishing the best practical environmental use of 'managed' re-use schemes in conjunction with existing resource schemes in London.

7.5 Redevelopment of Existing Reservoirs

- Establishing the viability of redevelopment and key issues considered to date including engineering appraisal, costs and environmental impacts/constraints.

7.6 Inter-regional Transfers

- Ongoing work to evaluate feasible transfer options; engineering requirements, costs and environmental appraisal.
- Further study to evaluate the following with regards all potential transfer schemes:

    * key water quality issues
    * possible impacts of transfer volumes and water quality on the ecology of receiving

waters

* impacts of transfers on fisheries, including spreading of fish disease and effects on migratory species
* mitigation requirements and remaining impacts of potential schemes

- Identification of operational constraints on transfers from the River Severn and its potential use with the proposed Abingdon reservoir; or the need for additional storage if the Abingdon scheme cannot be promoted.
- Identification of best practical environmental options for transfers from Anglian Region, potential beneficiaries and how schemes could be developed to meet future needs.
- Comparison of engineering, cost and environmental appraisal of transfer schemes compared to "favoured" regional options (eg. Abingdon Reservoir).
- Proving the availability and reliability of resources from the Anglian transfer schemes.