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COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS

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in Association with Cobham Resource Consultants

NATIONAL RIVERS AUTHORITY

NATIONAL WATER RESOURCES STRATEGY:

COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS

Volume 1: Main Report

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NATIONAL WATER RESOURCES STRATEGY

COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS

FINAL REPORT

VOLUME 1 - MAIN REPORT

CONTENTS

TABLES

After Page No.

FIGURES

TABLES

FIGURES

NATIONAL RIVERS AUTHORITY

NATIONAL WATER RESOURCES STRATEGY

COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS

FINAL REPORT

VOLUME 2 - APPENDICES

CONTENTS

APPENDICES CONTENTS (Cont.)

EXECUTIVE SUMMARY

INTRODUCTION

This report summarises the findings of a preliminary high level environmental assessment overview of strategic water resource development options identified by the NRA for meeting regional marginal water supply deficits in England and Wales up to a planning horizon of 2021.

This assessment has involved the following tasks:

- A literature review of the environmental issues and known impacts associated with water resources development schemes, including the effects of river regulation, inter-basin transfer and changes to residual flows to estuaries;

- A review of the impacts of existing UK schemes to identify the lessons to be learnt for future schemes;

- The development of a framework for assessment of individual schemes and objective comparison of strategic development options, taking account of EC and UK environmental assessment regulations;

- An assessment and comparison of the environmental implications of ten strategic options representative of the range of likely water resource developments, taking account of the results of hydrological modelling of specific schemes.

It is emphasised that this assessment is a starting point for environmental assessment of the strategic water resource development options collating, summarising and analysing the work carried out to date and identifying the key issues, constraints and benefits.

The approach, methodology and preliminary conclusions will be subject to progressive modification and development as more detailed studies and investigations are undertaken.

REVIEW OF LITERATURE AND EXISTING UK SCHEMES

The key findings from the review of the literature and existing UK schemes are:

- There are no generally accepted methods of determining environmentally acceptable flow regimes, although current research is starting to define minimum acceptable flows using habitat simulation models with salmonid fish as indicator species;

- Aquatic ecosystems respond in synergistic, complex ways to changes in the flow and quality regimes, which in any case have a high natural variability; the primary criteria for defining the acceptability of change is that flow regimes remain within the historic range of variation, that natural seasonality is preserved, and that the timing and magnitude of spates are adequate for migratory salmonids;

- There is no consistent approach to setting minimum residual flows (MRF) applied in the UK. There is still controversy concerning the "hands off" MRF to estuaries to protect salmonid migration. Some researchers claim that 50% of mean annual flow is required, whilst others propose that 1 to 2 times Q_{95} is adequate;

- There are inherent risks in transferring large quantities of water into adjacent catchments, which relate to biological integrity, transfer of pathogens and diseases, predatory species, and "fingerprinting" confusion for migratory salmonids. Particular risks are associated with transfers from the downstream end of large lowland rivers into the upstream end of upland or middle order reaches, due to the disruption of the nutrient cycle;

- The presence of existing low flow rate connections between catchments through the canal network, negates to some extent the arguments concerning biological integrity, although the proposed scale of transfers would be significantly greater;

- There has been a marked increase in the last decade in theoretical literature concerned with the ecological effects of river regulation, but there have been few studies of the specific effects of catchment transfers, and no environmental audits of transfer schemes have been carried out in the UK.

DEVELOPMENT OF ENVIRONMENTAL ASSESSMENT METHODOLOGY

A method for preliminary environmental assessment appropriate to a higher, more strategic level than project specific environmental assessment has been developed based on a literature review, review of the impacts of existing UK schemes, workshop sessions with NRA specialists and the expertise of those working on the project. The key features of the assessment framework are (see Figure 1):

- Each component, for example, regulated river/canal reach or new reservoir/pipeline, of an option is assessed separately;

- Categories used for assessment of components comprise;

Reservoirs/pipelines	Agriculture Community Impacts Archaeology and Cultural Heritage General Landscape Character Terrestrial Ecology Recreation/Amenity

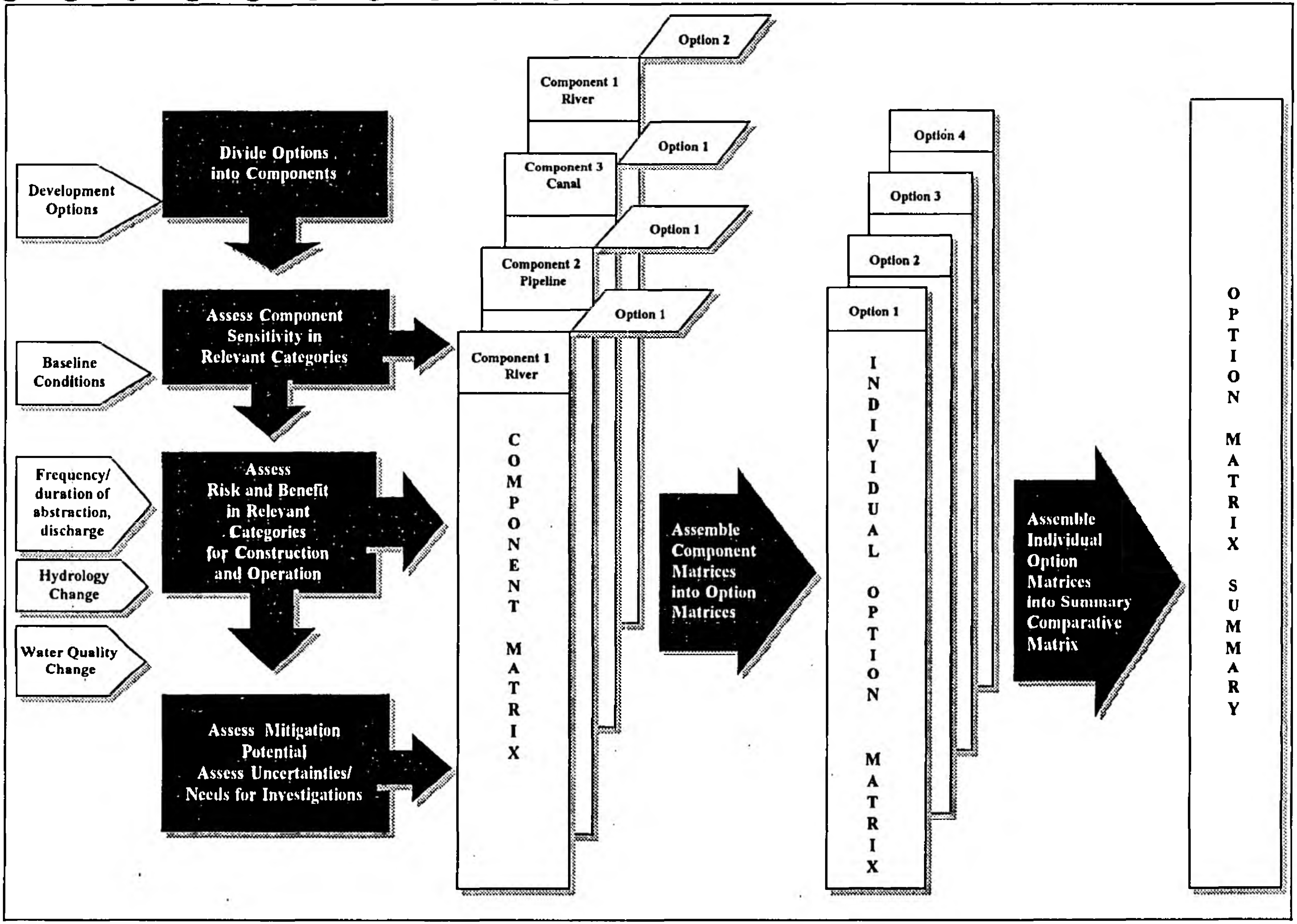

FIGURE 1 - ENVIRONMENTAL ASSESSMENT FRAMEWORK

Rivers/canals	Water Quality Fisheries Aquatic Ecology Terrestrial Ecology Recreation, Amenity and Navigation;

- Pipelines have been assessed in principle only, due to the number of possible variants on any individual transfer route;

- River and canal reaches at this level of assessment comprise complete tributaries, individual lengths of river of tens of kilometres, and estuaries; more localised issues and key sites may well emerge from detailed follow-on studies and investigation.

- The sensitivity, risk of adverse impact and benefit opportunities are assessed on a matrix basis with a 3 point scale (low-moderate-high) for each category, using explicit guideline criteria in order to make the assessment transparent and consistent;

- Options have been compared with matrices by considering the advantages and disadvantages of each component and also by indicating the environmental acceptability of an overall option from the NRA's perspective as an agency with statutory environmental protection responsibilities. An option is considered difficult to accept if it has a high risk of causing unmitigable loss/damage to highly sensitive fisheries, or aquatic/terrestrial conservation sites;

- The matrices used are a means of presenting the information and are not in themselves a method of decision making;

- Equal weighting is given to each category and criterion; this could be changed as appropriate in future development of the methodology;

PRELIMINARY ASSESSMENT OF STRATEGIC OPTIONS

The key environmental risks and opportunities for each option are summarised in Table 1 and are presented in Figure 2 as an overall impact matrix. Preliminary conclusions from the assessment at this strategic level are:

- The most environmentally sustainable and acceptable strategy is to manage demand such that as few schemes as possible are required within the planning horizon.

- Option 1 to transfer up to 400 Ml/d to the Thames at Buscot from the unsupported Severn may be acceptable. A suitable presecribed flow would be required to safeguard the lower Severn and the estuary. Serious consideration should be given to extending the pipeline to discharge to the Thames at Culham or into the proposed South West Oxfordshire reservoir. There are potential conservation and recreation benefits from renovating the Thames & Severn Canal. A detailed

Figure 2

COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS
SUMMARY MATRIX

DEMAND CENTRE	OPTIONS/COMPONENTS	SENSITIVITY								POTENTIAL ENVIRONMENTAL RISKS: CONSTRUCTION								POTENTIAL ENVIRONMENTAL RISKS: OPERATION								BENEFIT OPPORTUNITIES							
		Fish	Terr	WQ	Rec	Agr	Comm	Arch	Land	Fish	Terr	WQ	Rec	Agr	Comm	Arch	Land	Fish	Terr	WQ	Rec	Agr	Comm	Arch	Land	Fish	Terr	WQ	Rec	Agr	Comm	Arch	Land
THAMES	WYE/SEVERN – THAMES TRANSFER																																
	<u>Core Components:</u>																																
	Pipeline Deerhurst–Down Ampney Gravel Pits	•	•	•	•	•	•	•	•	•/	●/	•/	•/	●	•	•/	●/	/	/	/	/	/	/	/	/								
	Restored Thames & Severn Canal	·	·	·	·					·	·	·	·					•	·	·	·					•	•		●				
	River Thames Buscot–Egham	●	●	●	●					·	·	/	·					•	·	●	·					·			•				
	<u>Variable Components:</u>																																
	Unsupported–Severn d/s of Deerhurst	●	●	●	●					•/	·	•/	·					•/	·	•/	·												
	Enlarged Craig Goch Reservoir		●		·	·	·	•	•		●		•	·	·	•	•		●		·	/	/	•/	•		·		•	·	·	·	·
	Regulated Severn to Deerhurst	●	·	●	•					•/	·	•/	·					•/	·	•/	·					•	·	•	·				
	Regulated Upper Wye to Ross	●	●	●	•					•	•	•	·					●	•	•	·					·	·	·	·				
	Pipeline Ross–Deerhurst	•	•	•	•	•	•	•	•	•/	●/	•/	•/	●/	•/	•/	●/	/	/	/	/	/	/	/	/								
	River Vyrnwy regulated by redeployed Vyrnwy Reservoir	●	·	●	·					·	·	·	·					●/	·	·	·					·	·	·	·				
	Regulated Severn to Deerhurst	●	·	●	·					•/	·	•/	·					●/	·	•/	·					•		•					
	ABINGDON RESERVOIR																																
	Abingdon Reservoir		·		·	•	●	•	·		·		·	•	●	•	•		·		·	·	•	·	•/		●		●		·	·	·
	River Thames Culham–Egham	●	●	●	●					•/	/	•	·					●/	/	●/	·					•	·	•	•				
	BWB CANAL TRANSFER																																
	Pipeline Coalport–River Penk	•	•	•	•	•	•	•	•	•/	•/	•/	•/	•/	•/	•/	•/	/	/	/	/	/	/	/	/								
	River Penk to River Sow Confluence	•	·	•	·					·	·	·	·					•	·	·	·					•	·	●	·				
	River Sow to Heywood Jct.	•	·	•	·					·	·	·	·					·	·	·	·					•	·	●	•				
	BWB Canals:Heywood Jct.–Isis Lock	•	•	•	●					●	•	•	•/					•	•	·	·					•	·	●	•				
	River Thames d/s of Oxford Canal	●	●	●	●					●	·	●	·					●	·	●	·					·	·	·	·				
EAST MIDLANDS	SEVERN TRENT TRANSFER																																
	Pipeline Coalport–River Penk	•	•	•	•	•	•	•	•	•/	•/	•/	•/	•/	•/	•/	•/	/	/	/	/	/	/	/	/								
	River Penk to River Sow Confluence	•	·	•	·					·	·	·	·					•	·	·	·					•	·	●	·				
	River Sow to River Trent	•	·	•	·					·	·	·	·					·	·	·	·					•	·	●	•				
	River Trent d/s of Great Haywood	•	•	•	•					·	·	·	·					·	·	·	·					•	•	•	•				
ANGLIAN	GREAT BRADLEY RESERVOIR																																
	Great Bradley Reservoir		●		·	●	●	●	•		•		·	•	●	/	•		•		·	•	•/	•/	•/		•		●			·	•
	Tidal Ely Ouse/Wash	●	●	●	●													●	·	·	●/												
	River Stour	•	•	·	●					•	•	·	•					•	·	•	•					•	•	•	•				
	River Pant/Blackwater	●	·	•	●					•	•	·	•					●	·	•	•					•	•	•	•				
	UNSUPPORTED TRENT TO ESSEX TRANSFER																																
	Trent d/s of Torksey	·	·	•	●					·	·	·	·					/	/	•/	•/												
	River Witham	•	·	•	●					·	·	·	·					•	·	•	•/					·	·	·	·				
	Pipeline Witham to Ely Ouse	•	•	•	•	•	•	•	•	•/	•/	•/	/	•/	•/	/	/	/	/	/	/	/	/	/	/								
	River Stour	•	•	·	●					•	•	·	·					•	·	•	•					•	•	·	•				
	River Pant/Blackwater	●	·	•	•					•	•	·	·					•	·	•	•					•	•	·	•				
SOUTHERN	BROAD OAK RESERVOIR																																
	Broad Oak Reservoir		•		·	•	●	●	•		•		·	•	•	•	•		•		•	•	•	•	•		·		•	·	·	·	·
	Sarre Penn d/s of Reservoir	·	·	·	·					•	·	•	·					•	•	•	•					·	·	•	·				
	Great Stour estuary d/s of Plucks Gutter	•	·	●	·					•	·	•	·					·	·	·	·												

<u>CATEGORY KEY:</u>

- Fish: FISHERIES AND AQUATIC ECOLOGY
- Terr: TERRESTRIAL ECOLOGY
- WQ: WATER QUALITY
- Rec: RECREATION/AMENITY/NAVIGATION
- Agr: AGRICULTURE
- Comm: COMMUNITY IMPACTS
- Arch: ARCHAEOLOGY AND CULTURAL HERITAGE
- Land: GENERAL LANDSCAPE CHARACTER AND OTHER GENERAL PLANNING ISSUES

<u>LEGEND:</u>

- ● ● ● HIGH
- • • • MEDIUM
- · · · LOW
- / / / INDICATES IMPACT CAN BE MITIGATED

NOTE: Blank spaces indicate that the category is not applicable

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assessment of the likely chemical, biological and velocity changes at Buscot and downstream reaches of the Thames is essential;

- Option 2 to regulate the Severn using an enlarged Craig Goch may be difficult to accept because of the potential risk to an internationally important SSSI, loss of two other SSSIs, potential impacts on the high flow regime of the Wye, and an ecological/fisheries in the upper Severn; further studies are required to establish the scale of the conservation impact and the scope for mitigation; impacts on hydrology, river bed and ecology/fisheries in the upper Severn rivers need to be examined in detail;

- Option 3 to regulate the Wye using an enlarged Craig Goch should be eliminated from further consideration on environmental grounds because of the unique natural character of the river which is the best salmon river in England and Wales.

- Option 4 to regulate the Severn using a redeployed Vyrnwy reservoir would probably impact on salmon redds' spawning grounds in upper Severn tributaries, although this could perhaps be mitigated by new discharge arrangements. Knock-on effects of further developments in North West Region need to be investigated as do the impacts on hydrology, river bed and ecology/fisheries in the Vyrnwy, Tanat and upper Severn;

- Option 5 to construct an embanked reservoir in South West Oxfordshire appears to be an environmentally acceptable scheme, provided the short term construction impacts are deemed acceptable by the planning authorities, the impact on landscape can be mitigated, and subject to setting of suitable prescribed flow and release control rules following detailed assessment of effects on ecology/ fisheries;

- Option 6 to transfer up to 100 Ml/d from the Severn to the Thames via the BWB canal system requires a large amount of construction works required along 200km of canals, and has inherent risks to the water quality of the Thames.

- Option 7 to transfer up to 100 Ml/d to the upper Trent from the Severn appears to be environmentally acceptable. The scheme would have less impact if the transfer was made direct to the Sow rather than via the Penk, because the proposed transfer could lead to macrophyte wash out and channel scour, although the Penk has already been the subject of recent channel improvements. There are potential water quality benefits to both the Sow and the Trent.

- Option 8 to construct a reservoir at Great Bradley needs to be carefully reviewed. At the proposed top water level of 105.5m AOD the scheme would mean the loss of ancient woodland SSSIs and 77 properties. A lower water level (99m AOD) would have significantly less effect. Alternative sites for a storage reservoir along potential transfer routes should be investigated. The implications of changes to the flow regime of the tidal Ouse downstream of Denver on siltation and ecology of the Wash require further study.

- Option 9 to transfer up to 200 Ml/d from the unsupported Trent to the Ely Ouse-Essex scheme via the Witham is an increased rate for an existing transfer scheme. A prescribed flow for the Trent would need to be set allowing for restoration of migratory fisheries if this is a long term objective for the river. Further studies of the water quality implications of the increased transfer and channel enlargement works on receiving watercourses are required.

- Option 10 to construct a reservoir at Broad Oak appears environmentally acceptable on the basis of the limited information made available for this study. The impacts on the Sarre Penn and the Great Stour can be minimised by adopting appropriate control rules, and by appropriate setting of a prescribed flow.

- There may be other variants of the assessed options, eg longer pipelines or lower reservoir top water levels, which have significantly less impacts or important benefits.

- Alternative options such as desalination or undersea pipelines all have environmental advantages and disadvantages and may have a part to play in exceptional circumstances.

REQUIREMENTS FOR FURTHER STUDIES

Further study requirements include strategic studies relating to NRA policy and option specific studies to improve understanding of the environmental implications and baseline conditions for the more acceptable options. Option specific studies are best carried out by those promoting the schemes, although some fisheries, water quality and prescribed flow studies fall within the NRA's remit. The NRA should ensure that adequate option specific baseline data exists for all options for which licence applications may eventually be received.

LIMITATIONS OF ASSESSMENT

The main limitations of this assessment are:

- It has been confined to the strategic options identified by the NRA through a process of preliminary cost estimates, environmental considerations and cost-minimisation studies using the RESPLAN model, however, these are representative of the range of likely water resources developments;

- Specific quantities, operating rules and route alignments were selected by the NRA and do not necessarily represent the environmental optimum;

- No fieldwork or examination of primary data has been carried out for this study, it is based on existing reports and analyses carried out by others and discussions with NRA regional staff;

- The amount of reliable baseline data varies considerably; different options have therefore been assessed to different levels of detail;

- Knock-on environmental implications, such as the development of new resources in North West region in order to redeploy Vyrnwy, and several local schemes, such as Carsington, were excluded from this study;

- Although the approach adopted has been to consider the "worst case" for transfer quantities, the cumulative effects of different possible combinations of schemes and other local developments have not been assessed, and should be investigated.

TABLE 1 KEY ADVANTAGES AND DISADVANTAGES OF STRATEGIC OPTIONS

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 1: Severn - Thames Transfer Transfer of 400 Ml/d to Thames at Buscot from Unsupported Severn	Does not involve significant engineering works Benefits through renovating the Thames - Severn Canal Increased flows may prove beneficial in supporting low flows to upper Thames and possible reduction in frequency of channel maintenance Given existence of good quality tributaries, impacts on aquatic ecology may be short lived (or might recover from downstream drift) No adverse effects on recreation	Upper Thames might become more than 80% lower Severn water during low flow periods with significant changes to biochemistry impacts on water quality and transfer of disease, parasites, bioaccumulation Impact on the aquatic ecology of donor and recipient rivers Effects of transferring up to 4 times dry weather flow could impact on morphology, habitat, washout or fish fry and macroinvertebrates	The key issues relate to establishing water quality and biological impacts Extending the pipeline to discharge into South West Oxfordshire reservoir for blending would make this scheme more acceptable. It is important to ensure that downstream SSSIs near Deerhurst are not adversely affected and that there are sufficient residual flows to allow for salmonid migration up the Severn Fisheries interests would be a key issue Might need to consider operation in conjunction with Farmoor reservoir (without South West Oxfordshire reservoir)
Option 2: Enlarge Craig Goch Reservoir Transfer to Thames at Buscot from the Severn Regulated by an enlarged Craig Goch	Severn already regulated and instream impacts unlikely to be significant, although care should be taken to ensure some marginal seasonal-dry, gravel-cobble habitats are exposed Moderate recreation benefits from construction of reservoir No long term adverse water quality implications foreseen No impacts on reach downstream of Deerhurst since abstracted quantity would be balanced by reservoir releases	Significant adverse effects on sites of nature conservation arising from enlargement of Craig Goch, including partial loss of internationally important SSSI at Elenydd Significant local effects on the extent of inundation of salmonid nursery areas in late summer will need further research Frequency and duration of high flows over the summer months would be severe	Adverse effects on sites of nature conservancy value are likely to be significant issues affecting acceptability

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 3: Enlarged Craig Goch Transfer to Thames at Buscot from the Wye Regulated by an Enlarged Craig Goch	Major changes likely to be confined to a short reach downstream of the Ithon confluence Moderation of extreme flow ranges may provide benefits in improved habitat stability Regulation of the Wye is dependent on water releases from the upper catchment (Craig Goch) which is unlikely to adversely affect water quality within the Wye	The natural condition of this river is rare in the UK, it is an SSSI Peak regulation releases of 400 Ml/d into the Wye at Nannerth will significantly impact on the flow regime (habitats and ecology) of a 6 km reach of the river Principal concerns relate to the extent that the altered flow regime will affect salmonid spawning reaches Transfer of Wye derived water from Deerhurst to Buscot could have adverse impacts Low level of similarity between instream fauna of the River Wye at Ross-on-Wye and the River Thames at Buscot	There are a number of uncertainties relating to environmental and water quality implications of this transfer. In general this scheme appears to have adverse nature conservation implications due to the enlargement of Craig Goch and regulation effects on the River Wye Impacts for channel morphology and channel bed stability/sedimentation have not been assessed
Option 4: Redeployed Vyrnwy Reservoir Redeployment of Vyrnwy to Regulate the Severn	No significant infrastructure associated with redeployment Use of multiple draw-offs to mitigate temperature and water quality problems likely to mitigate impacts on aquatic ecology	Major impacts on low-flow regime for more than 30 km Vyrnwy is an important salmonid river and reservoir releases will affect main spawning and juvenile reach. Maintenance of stable nursery areas without excessive washout will need further consideration	Downstream implications for wetland habitats require further research

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 5: South West Oxfordshire Reservoir Construction of New Reservoir at Abingdon to Regulate the Thames	No scheduled ancient monuments affected No landscape/planning designations affected Impacts on agriculture are considered moderate/low Significant recreational resource coupled with nature conservation benefits Possible benefits to Wiltshire-Berkshire canal	Considerable local construction impacts for many years Visual impacts significant Effects on land drainage would need mitigation Would require effective control and management of abstraction, discharge and stored water to minimise potential effects on water resources and water quality Possible algal development Post construction recreation and transport pressure	Considerable construction impacts, significant visual impact Downstream implications for wetland habitats require further research
Option 6: Canal Transfer Transfer to the Thames at Oxford from the Regulated Severn via BWB canals of 100 Ml/d	Water quality improvements in certain stretches of canal Long term amenity and recreational benefits Increase in flow velocities to 0.5 m/s could enhance coarse fisheries due to increased DO and less siltation	Water quality problems associated with discharge of eutrophic and polluted water to the Thames Possible adverse effects on instream ecology and fisheries associated with dredging Increase in flow velocities may impact on navigation Visual and amenity disturbance associated with construction works along 200 km of canals Some stretches include SSSIs and other restrictive planning designations Possible further spread of fish species	The water and environmental quality implications for the Thames would require considerable further investigations

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 7: Severn to Trent Transfer Severn to Trent Transfer via Penk and Sow of 100 ml/d	Effects on abstractors negligible No adverse effects on water quality on the Severn Possible water quality benefits for the River Penk, the River Sow and the River Trent Impacts upon low flows within the Upper Trent is likely to be beneficial, maintaining a diversity of habitats during drought years	High local impacts on aquatic ecology in the Penk and Sow (although it should be noted that the biological quality is moderate to low) Possible transfer of fish disease (Pomphoryncus) to the Trent. Disease is not thought to have caused fish mortalities elsewhere.	Site specific planning constraints along pipeline route need more detailed research and sufficient flows in the Severn are needed to allow for upstream migration of salmonids
Option 8: East Anglian Reservoir Great Bradley Reservoir and Existing Ely Ouse-Essex Scheme Note: These comments apply only to a new reservoir at Great Bradley. At least one other potential site is available, yet to be studies in the same detail, for which the impacts will be different	Construction of a reservoir at Great Bradley would provide significant long term nature conservation and recreational opportunities Potential improvements might accrue in the quality of water transferred from the existing Ely Ouse scheme to the Rivers Stour and Pant by the introduction of interim storage within Great Bradley. The reservoir would also enable improvements to be made in the timing and rate of releases An environmentally sensitive approach to channel modifications in the Rivers Stour and Pant could redress some of the adverse effects of historical regulation works on aquatic ecology	Four ancient woodland SSSIs and a further five ancient woodlands would be affected by reservoir construction Loss of residential properties due to reservoir construction; a significantly smaller number of properties and area of woodland would be affected if a small reservoir is constructed Possible adverse effects on siltation, water quality, fisheries and ecology of the tidal Ely Ouse and the Wash Estuary SSSI/Ramsar Site due to reduction in flows in tide Increased flow releases to the Rivers Stour and Pant are likely to affect instream ecology Increased transfers are likely to affect water quality characteristics of the River Pant	As with all reservoirs, it is likely to be subject to considerable local opposition. If a small reservoir is constructed the advantages are similar but the disadvantages are considerably reduced Impacts on regulated rivers could be ameliorated by sympathetic operation (timing and rate)

	Advantages	Disadvantages	Environmental Acceptability
Option 9: Trent to Anglian Transfer Unsupported Trent to Essex Transfer of up to 200 ml/d	No major water quality impacts downstream of Torksey No adverse effects on recreation in the Trent No significant adverse effects on water quality in the Witham Fisheries impacts arising from abstraction will be minimal Increase in velocity in Fossdyke unlikely to affect value of fishery No major impacts on the aquatic ecology of the Witham	Reduced freshwater inputs to the Humber Estuary needs further research Impact of reduced flows on siltation/ navigation needs further research Change in aquatic fauna in the Fossdyke is likely to occur. Marginal macrophyte beds are essential to sustain low-velocity habitats in this channel Potential water quality problems (eg organophosphates and sulphates) in the Trent being transferred to the Witham and Essex rivers Possible adverse effects on angling in the Witham Impact of 57Kms pipeline/tunnel during construction	This scheme is acceptable provided concerns about transferring lower quality Trent water into the Ely Ouse-Essex scheme can be overcome through further studies, and if necessary, treatment of contaminants such as phosphates and sulphates Impacts on regulated rivers could be ameliorated by sympathetic operation (timing and rate)
Option 10: Broad Oak Reservoir	It is understood that the reservoir mainly occupies improved farmland (Grade 3) and few buildings would be inundated Given appropriate operational rules to ensure normal recovery in the autumn; the scheme need not impact upon the instream aquatic ecology	Possible changes in water quality as a result of reduced dilution of sewage effluent and urban run-off and possible changes to saline and silt regime in the estuary Sarre Penn is a SNCI	This option is acceptable provided appropriate operating rules are included to control abstractions from the Stour and releases to Sarre Penn Need to ensure periodic flooding for downstream wetland sites

1. INTRODUCTION

1.1 Background

The National Rivers Authority (NRA) has a duty to ensure the proper and efficient use of water resources, whilst protecting and improving the environment. Under Section 188 of the Water Resources Act 1991 it also has a duty to publish information from which assessments can be made of actual and prospective demands for water and actual and prospective available water resources in England and Wales. In fulfilment of these duties, the NRA is committed to publishing a strategic framework for the development of new water resources in England and Wales to meet potential demands up to the year 2021.

The strategic framework is not intended to be prescriptive, rather, it must be flexible enough to respond to variations between forecast and actual patterns of demand and to accommodate potential changes in resource availability caused by climate change. At the same time, the strategic framework must encourage the promotion of schemes which are both economically and environmentally acceptable. The national strategy document will provide a structure within which any applications to develop specific schemes can be assessed. The purpose of the national strategy document is to indicate the sequence of likely developments, their magnitude, impacts and probable timing, and to highlight the associated environmental issues.

The development of the strategic framework is multi-disciplinary, involving yield assessment, demand forecasting, resource engineering, costing and environmental assessment. The difference between estimated demand and local resources has identified regional marginal deficits for four forecast scenarios at 5 year intervals from the base year 1991 up to the planning horizon 2021. A broad range of strategic options has been investigated for meeting these marginal deficits. The strategic options include potential new sources and schemes for transfer of additional water to centres of marginal deficit.

The NRA appointed Howard Humphreys & Partners Ltd (HHP) in association with Cobham Resource Consultants (CRC) to undertake an independent strategic level environmental assessment (EA) of the possible development options under consideration. Full terms of reference (ToR) are included in Appendix A. This final report summarises the findings of the study.

1.2 Objectives and Tasks

The objective of this environmental assessment is to ensure that likely options for inclusion in the national water resources strategy are environmentally assessed on a comparable basis, the main issues and any impacts which are likely to occur are identified, mitigation measures are identified wherever possible, and opportunities for environmental benefit are maximised.

The tasks identified in the ToR were to:

- undertake a literature review of the environmental issues and known impacts associated with water resources development schemes, including the effects of river regulation, inter-basin transfer and changes to residual flows to estuaries;
- review the impacts of existing UK schemes and identify the lessons to be learnt for future schemes;
- collate and review the environmental assessments of particular strategic development options undertaken by others;
- develop a framework for assessment of individual schemes and objective comparison of strategic development options, taking account of EC and UK environmental assessment regulations where appropriate;
- apply the framework to compare the environmental implications of each development major option, taking account of the results of hydrological modelling of specific schemes.

1.3 Scope of Study

This report is not a detailed environmental impact assessment (EIA) of all possible water resource development options for England and Wales. When specific schemes are proposed with detailed locations, capacities and operating rules, then these will require a project specific EIA in accordance with current legislation. Rather, this report provides a comparison *at a strategic level* of NRA selected alternative options for meeting national and regional water supply deficits. The options include a representative range of types of water resources development.

A discussion of the role of strategic environmental assessment and how this relates to the present study is given in Section 4.1. In principle, a strategic environmental assessment should be applied to policies, plans and programmes but this was not the approach taken in the ToR (Appendix A), and this study is better described as an environmental assessment of NRA selected strategic options. A brief discussion of some of the key strategic issues is included in Chapter 6.

The ten options which are assessed in detail in Chapter 5 were identified by the NRA through a process of preliminary cost estimates, environmental consideration and cost-minimisation studies using the RESPLAN model.

1.4 Limitations of Study

The limitations of this study are:

- No fieldwork or examination of primary data has been carried out for this study, it is based on existing reports and analyses carried out by others;
- Different options have been examined to different levels of detail, depending on the data available;
- Where detailed option studies exist, the amount of reliable baseline data also varies considerably. Requirements for baseline studies are highlighted in Chapter 7;
- Specific quantities, operating rules and route alignments were selected by the NRA and do not necessarily represent the environmental optimum;
- Knock-on environmental implications, such as the development of new resources in North West region in order to redeploy Vyrnwy, have not been considered;
- The approach adopted has been to consider the "worst case" for transfer quantities, however, the cumulative effects of different possible combinations of schemes and other local developments has not been assessed.

Notwithstanding these considerations, this study has been as wide ranging as possible and it provides an independent assessment on a comparable basis of the potential environmental risks and opportunities associated with all the major strategic options under consideration by the NRA.

1.5 Scope of Report

This report contains the following:

- A description of the approach taken by the NRA to identify the key options which are considered in detail in this report, and the other studies upon which this assessment is based (Chapter 2);

- The findings of the literature review of current knowledge concerning the responses of physical and biological systems to changes in flow regimes; a summary of the perceived/measured impacts of existing major UK water resources schemes; and the outcome from a series of NRA consultation workshops held as part of this study (Chapter 3) (the full literature review and assessment of existing UK schemes are included in Appendices B and C);

- A description of the framework for assessing and comparing the strategic options, together with a discussion of its development and limitations (Chapter 4);

- A detailed assessment of the environmental implications of the individual components of each of the ten key strategic options, including specific mitigation measures where feasible, benefit opportunities and a comment on the environmental acceptability of individual scheme components (Chapter 5);

- A comparison of alternative ways of meeting regional marginal deficits and a discussion of key environmental issues for each strategic option (Chapter 6);

- Detailed studies required before schemes could be further assessed and additional strategic studies arising from this assessment (Chapter 7);

- The conclusions of the study and recommendations as to priorities for further studies (Chapter 8).

2. IDENTIFICATION OF STRATEGIC OPTIONS

2.1 Selection of Strategic Options

The methodology adopted by the NRA for selecting the key strategic options has had important implications for the scope of this study, and in particular for the level of detail at which different options have been assessed.

An initial appraisal was made of existing resources and future demands on a region-by-region basis, and a scoping report prepared of options for meeting regional deficits. The data for this study were based on existing water company demand forecasts and existing yield estimates for regional sources. The findings of this study are summarised in the NRA/Halcrow R&D Note 35 Water Resources Planning - Strategic Options (1991).

Following on from this, the NRA carried out independent regional demand forecasts for a range of scenarios from totally uncontrolled high demand with existing leakage levels to fully managed low demand with high leakage control targets up to the planning horizon of 2021. A consistent methodology was applied so that estimates are comparable between regions. The NRA also revised the yield estimates for existing licensed sources.

At the same time, detailed engineering and environmental studies were commissioned by the NRA regions affected by potential deficits both to review within region options and to examine the main inter-basin transfer options. A full list of all option studies is included in Appendix E. The less attractive options identified in the initial study were taken to a greater level of detail in a separate report on "Other Options" by Halcrow (1993). All options were then put onto a consistent basis for costings.

Each of the regions carried out water resources modelling and hydrological simulations to identify the availability of resources and the maximum resource value of different transfer and storage options. The results of these simulations for different peak transfer rates and storage volumes were combined with marginal deficit information to calculate the with/without scheme hydrology for donor and recipient catchments and also the expected frequency of operation. The results of these hydrological studies were summarised in internal reports and memos which formed an important input to the environmental assessment.

A resource development optimisation model, RESPLAN, was then used to identify the least cost combinations of new sources and transfer routes to meet marginal deficits at regional demand centres for each planning horizon using different demand forecasts. The sensitivity of the results to different cost assumptions for the key options was also checked.

On this basis ten strategic options representing a wide range of development types were identified for environmental assessment in this study. The ten options were therefore been selected through iteration and elimination on the basis of preliminary cost estimates, resource value, refined cost estimates and preliminary environmental assessment of sub-options (eg alternative pipeline routes or alternative reservoir storage levels). This process resulted in some possible options being excluded from detailed assessment, for example Kielder transfers south or BWB canal transfers from the North West to Anglian.

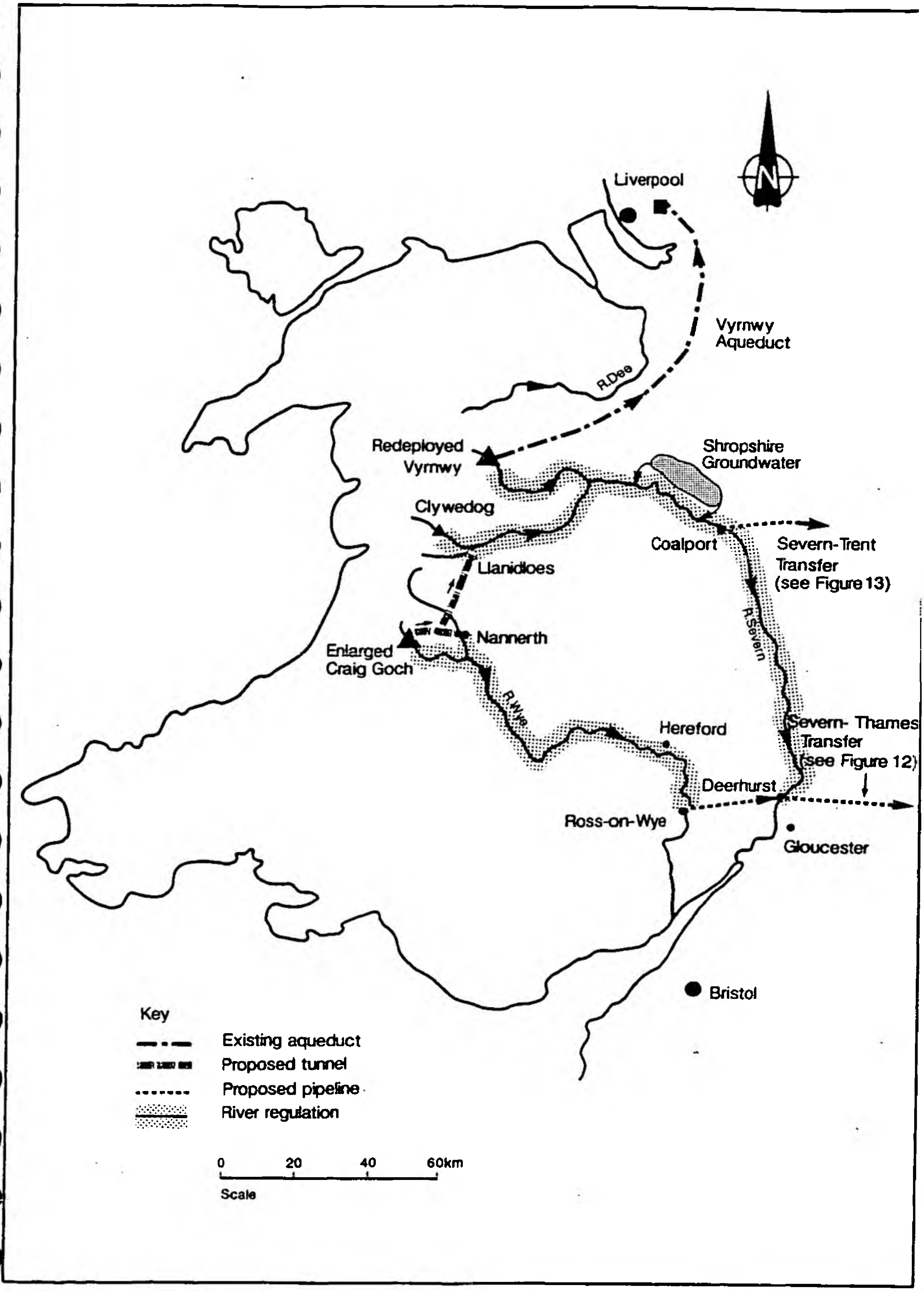
The level of information upon which the environmental assessments included in Chapter 5 are based varies from the Severn-Thames transfer for which detailed hydrological studies, water quality mass-balances and other baseline environmental data are available on one extreme, to the regulation of the Wye on the other, for which limited up-to-date baseline data and no simulation studies were available.

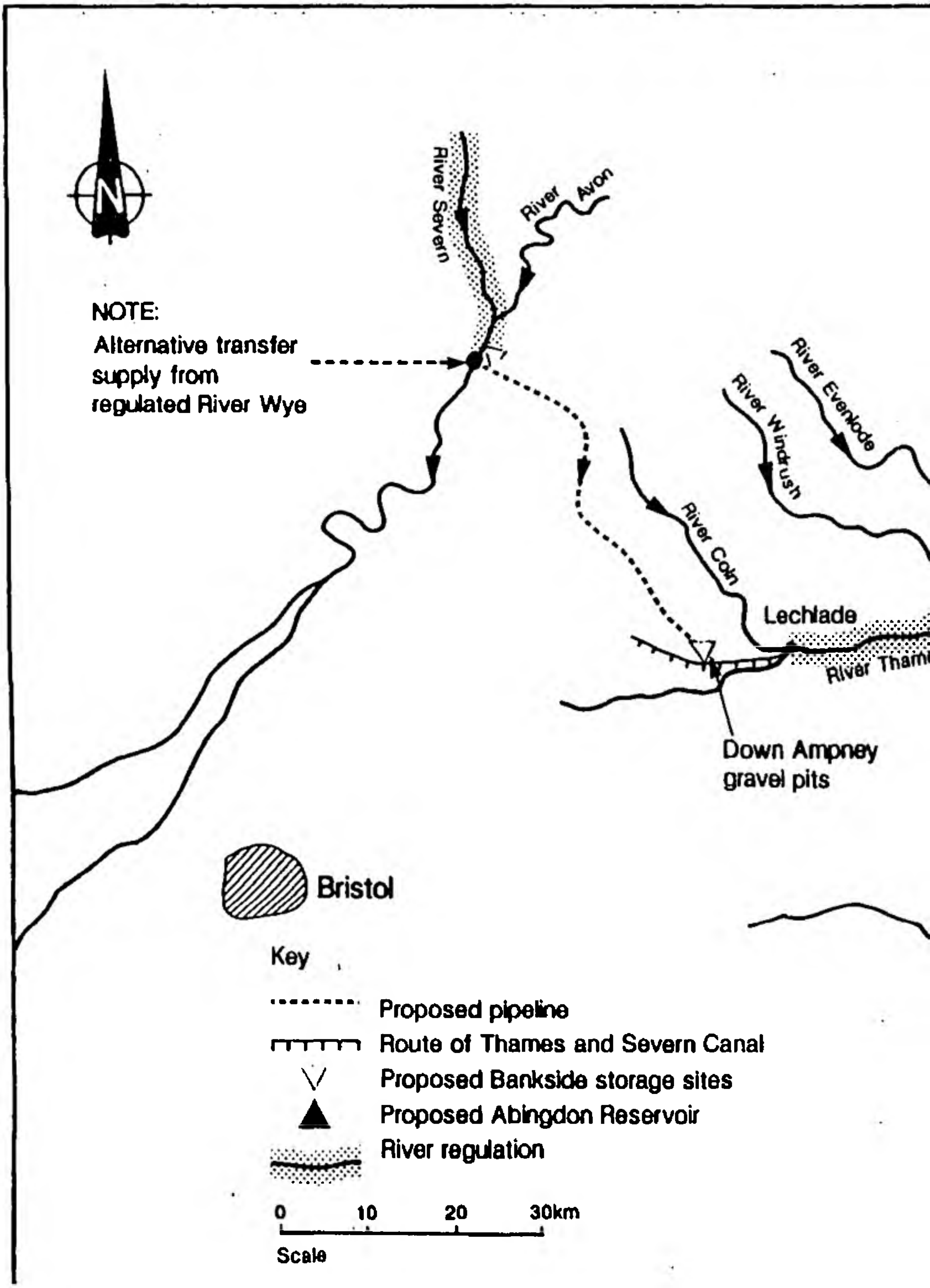
2.2 Strategic Options

The ten water resources development options identified as a result of the above studies were (see Figures 2.1 to 2.4):

- unsupported Severn to Thames transfer
- Craig Goch supported Severn to Thames transfer
- Craig Goch supported Wye to Thames transfer
- Vyrnwy supported Severn to Thames transfer
- South West Oxfordshire Reservoir regulating Thames
- Severn to Thames transfer via River Penk, River Sow, Trent and Mersey Canal, Coventry Canal and Oxford Canal
- Severn to Trent transfer via River Penk and River Sow
- Great Bradley Reservoir supported by Ely Ouse-Essex transfer scheme
- Unsupported Trent to Essex transfer
- Broad Oak Reservoir.

FIGURE 2.1 - RIVER SEVERN REGULATION OPTIONS





N
River Severn
River Avon
NOTE:
Alternative transfer supply from regulated River Wye
River Evenlode
River Windrush
River Coln
Lechlade
River Thames
Down Ampney gravel pits
Bristol
Key
Proposed pipeline
Route of Thames and Severn Canal
Proposed Bankside storage sites
Proposed Abingdon Reservoir
River regulation
0
10
20
30km
Scale

FIGURE 2.2 - SEVERN-THAMES TRANSFER AND SOUTH WEST OXFORDSHIRE RESERVOIR OPTIONS

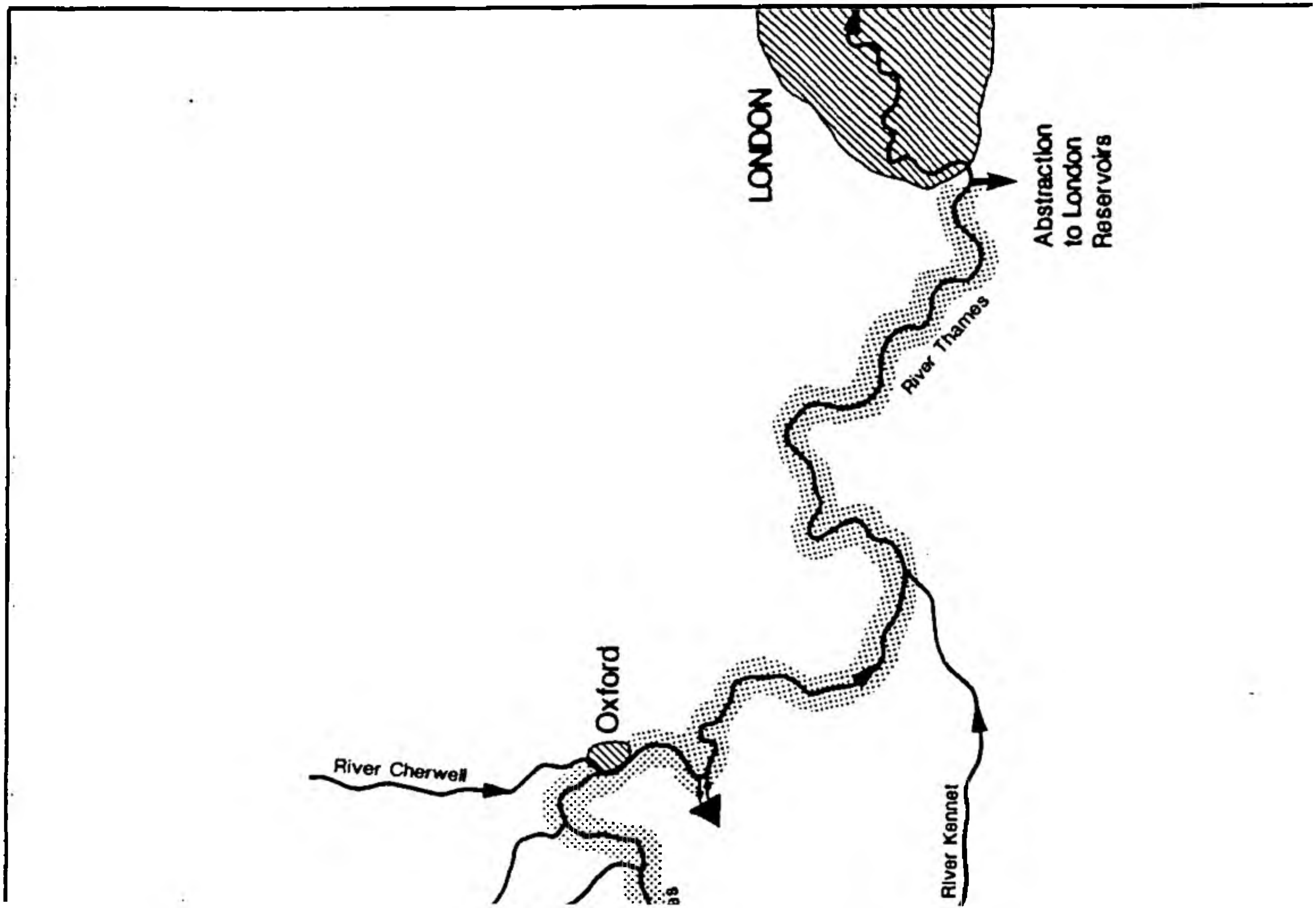


FIGURE 2.3 - SEVERN-THAMES CANAL TRANSFER AND SEVERN-TRENT TRANSFER OPTIONS

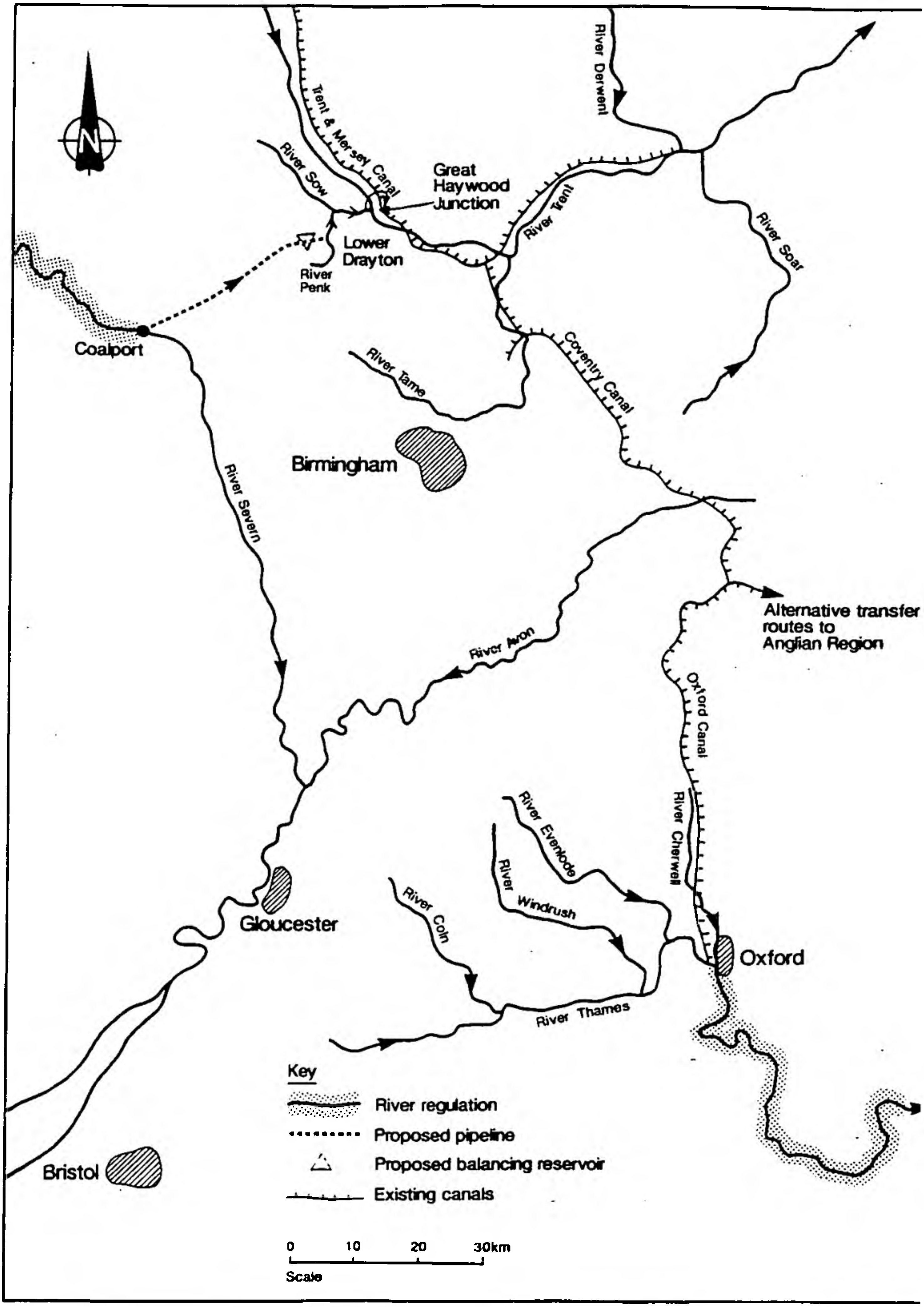
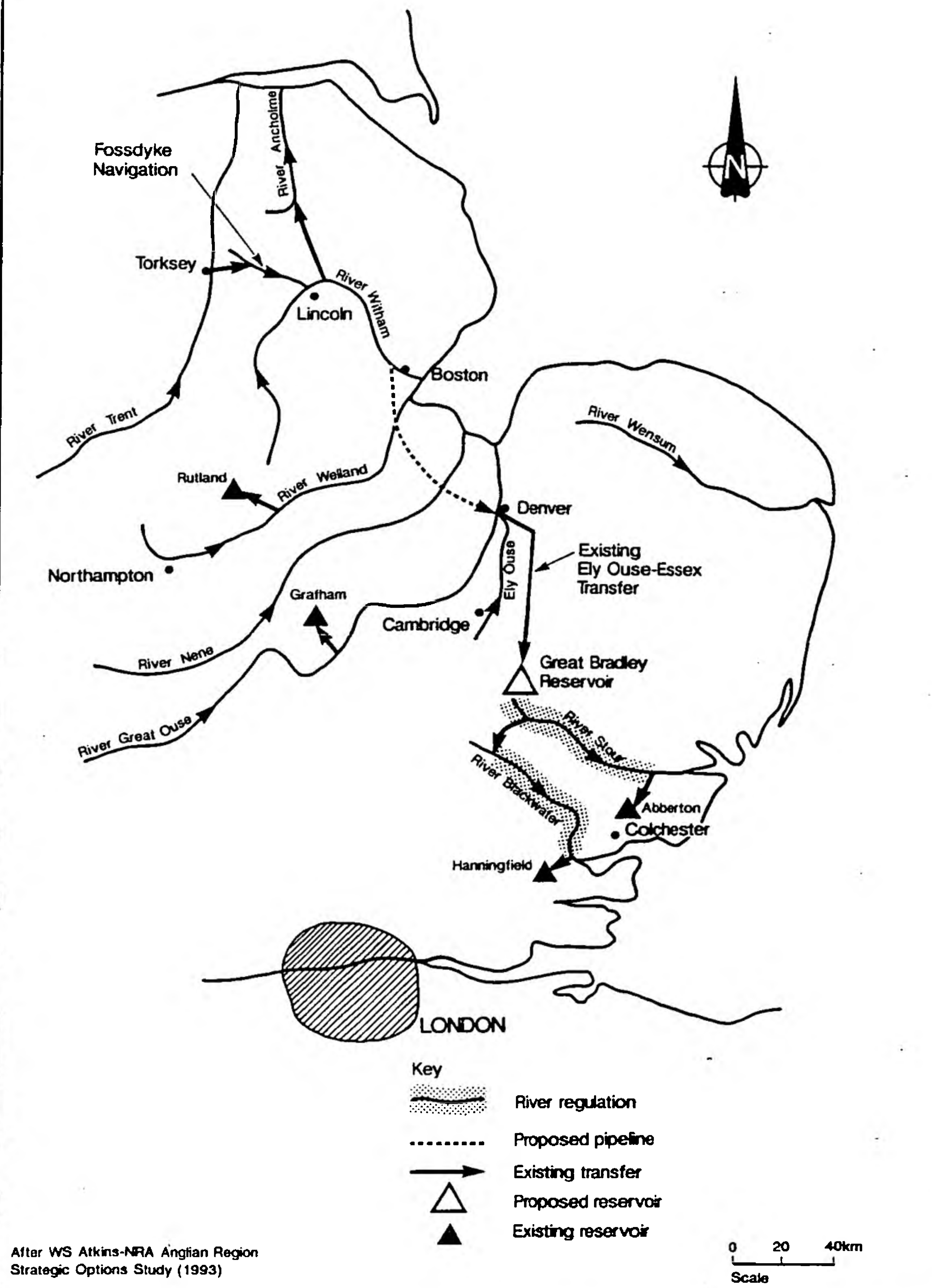


FIGURE 2.4 - TRENT-ESSEX TRANSFER AND GREAT BRADLEY RESERVOIR OPTIONS



After WS Atkins-NRA Anglian Region Strategic Options Study (1993)

3. LITERATURE REVIEW AND UK EXPERIENCE

3.1 Key Findings from Literature Review

A literature review was undertaken with the aim of identifying:

- International experience of similar schemes;
- The known physio-chemical impacts associated with schemes with similar components to those in the NRA strategy and the opportunities for mitigation;
- The known biological impacts associated with schemes with similar components to those in the NRA strategy and the opportunities for mitigation;
- The predictability of changes;
- Criteria for defining acceptable flow regimes.

The review concentrated on aquatic impacts related to changes in flow and quality, on the grounds that terrestrial impacts are covered by general planning regulations. Terrestrial impacts can be categorised as either damage or loss, such as when a Site of Special Scientific Interest (SSSI) is inundated by a reservoir. Instream aquatic ecology is likely to be significantly affected by the potential schemes, but its relationship to flow and quality regimes is usually poorly understood.

The full literature review is included in Appendix B. The key findings of the review were:

- Interbasin transfers are common throughout the world and have been implemented on a scale far greater than anything proposed in the UK.
- The key issues identified in the literature relate to: scale (larger scale equals higher risk); appropriateness (alternative strategies which obviate the need for transfers must be considered); integration (the quality and quantity implications of all projects must be assessed in an integrated way).
- Both the high flow, medium flow, and low flow regimes play important roles for different elements of the aquatic environment.
- The high flow regime is important for "flushing" silts and sediments through the river system and into estuaries. High flows are important triggers for migratory fish and influence the extent of saline intrusion up a tidal river.

- The medium flow regime defines the "climate" to which the aquatic environment is adapted. Significant changes, particularly to the seasonality and variability of flows may cause unexpected changes to the aquatic ecosystem.

- The low flow regime is crucial, both in maintaining a survival flow for depth sensitive organisms such as fish, and for maintaining adequate dilution of effluents influencing water quality.

- Despite a recent increase in research, the complex interactions between flow regimes and aquatic ecology are poorly understood. The habitat preference curves used in the Instream Flow Incremental Methodology are starting to provide a rational basis for setting minimum environmentally acceptable flows, but the methodology has a long way to go before seasonal flow changes, water quality and aquatic ecology changes can be fully correlated and assessed.

- Provided a water resources scheme is operated so as to maintain a quantity and quality regime which is set with reference to natural conditions, then a healthy aquatic environment can be maintained. The key yardstick for acceptable changes to existing flow regimes appears to be to maintain the existing natural seasonality, variability, frequency of low flows and timing of spates.

- There is no generally recognised method for setting minimum "hands off" prescribed flows in rivers or minimum residual flows (MRF) to estuaries. However, given that most discharge consents are made with reference to an existing low flow statistic, usually Q_{95}, then a prescribed flow above this value seems sensible. There is still controversy about appropriate settings for estuaries to protect salmonid migration. Proposals range from 1 to 2 times Q_{95} up to 50% of mean flow.

- Given the complexities of predicting the changes to an entire aquatic ecosystem, a pragmatic approach is to maintain acceptable conditions for a sensitive target indicator species whose requirements are well understood. This is usually taken to be salmonid fish or flowing water cyprinids. The philosophy is that the presence of these species is an indicator of a healthy aquatic environment.

- There are inherent risks in transferring large quantities of water into adjacent catchments, which relate to: biological integrity; subtle chemical alterations; transfer of pathogens and diseases; transfer of predatory species; "fingerprinting" confusion for migratory salmonids. Particular risks are associated with transfers from the downstream ends of large lowland rivers into the upstream end of upland or middle order reaches, due to disruption of the nutrient cycle.

- The similarity between the donor and recipient stream of an interbasin transfer is a vital factor in determining its ecological effect.

- Biota are highly sensitive to changes in:

    - Water quality;
    - Hydrology;
    - Substrate.

  These are all influenced as a result of interbasin transfers.

- As a result of the transfer of biota between catchments and rivers, and the factors above, the ecological integrity of many rivers influenced by transfers is under threat.

- The scale of impact of a scheme is likely to reduce downstream and is unlikely to have any ecological effects once the catchment area of the impoundment is less than 35 per cent of the total drainage area.

- The magnitude and frequency of discharges into recipient streams may have serious implications for small headwater streams.

- Further research is needed into interbasin transfers within the U.K. to identify the specific ecological effects.

- For fisheries, the key factors affecting populations are: changes in velocity; loss of spates/freshets; changes in habitats; changes in downstream temperature regimes; quality changes; introduction of new species or disease risk. All these factors require site specific data.

3.2 Key Findings From UK Experience

There is considerable experience of major river regulation, augmentation and transfer schemes in the UK. The perceived and measured actual impacts of these schemes can provide valuable information on the range and severity of impacts under UK conditions. Experience of operating such schemes over several years can identify opportunities for mitigation of impacts and environmental enhancement. A review of the UK experience was undertaken based on information provided by the NRA.

The NRA identified 29 schemes covering all of their 9 regions, where there had been a significant impact on the flow regime. The majority (21) are river regulation schemes, 6 involve groundwater augmentation of rivers, and 4 involve transfers of raw water (note that 3 are multi-component schemes).

The summary sheets produced by the NRA Regions for the major schemes in each region are included in Appendix F. This information does not necessarily reflect all the data available within the regions. Tables summarising the measured/perceived impacts are included in Appendix C together with a more detailed commentary on six existing schemes for which some baseline data were available. Very little post-scheme evaluation appears to have been carried out, even in the regions with major transfer schemes. The majority of schemes include river regulation or groundwater augmentation to support abstraction and maintain quality within the same catchment. The impacts in terms of the objectives of the schemes are therefore invariably considered as beneficial.

Despite the lack of firm evidence from pre/post- scheme evaluations, transfer and flow regulation are reported to have had an impact on river ecosystems in England and Wales, often creating gradual but significant changes over long periods of time. Some general conclusions concerning use of groundwater augmentation, interbasin transfer and reservoir impoundment based on the limited information made available by the NRA are given below.

Augmentation by Groundwater

The positive impacts generally relate to improvements in water quality arising from increased dilution, and amenity benefits due to enhanced flows. The negative impacts largely relate to effects on fisheries from reduced temperatures and flow changes. For some schemes there were no identified impacts.

Interbasin Transfer

Increased flows provide opportunities to flush pollutants and aid dilution, give additional opportunities for angling and increase leisure opportunities. Considerable negative impacts were identified/perceived and include increased erosion, algal blooms, transfer of disease, transfer of pollutants, changed flow rates adversely affecting fish behaviour and spawning, and the transfer of alien fish eggs and larvae.

Regulation by Impoundment

Positive impacts are identified as general enhancement of flows benefitting aquatic ecology, formation of valuable wetland habitats in reservoirs, controlled releases increasing recreational opportunities and resulting in marginal benefits for fisheries. Negative impacts relate to increased scour below dams and compaction of gravels, changes in water quality from storage, reduced upstream fish migration, increased siltation, reduced macroinvertebrate populations, landtake affecting terrestrial ecology and conflicts between release requirements and water users. A number of schemes were reported to have no identified impacts.

3.3 NRA Consultation Workshops

The scheme summary sheets were combined with the information gleaned from the literature review to produce draft scoping of issues, key environmental receptors and impact criteria for all categories of scheme component being considered as part of the national water resources strategy. Four consultation workshop sessions were held on 24th and 25th June 1993 at NRA Headquarters, London. Each session covered a broad category of impact corresponding to the NRA functions of Water Resources; Water Quality; Fisheries; Ecology/Conservation; Recreation/Amenity and Navigation. At least one relevant specialist from each NRA region attended every session.

There was a notable difference between physical and biological disciplines in their acceptance of broad categorisation of impacts and adoption of criteria for defining severity. Physical impacts which threatened statutory duties related to discharge, depth or water quality were categorised as high impacts. Extremely useful discussions were held on the topics of simple hydrological criteria and the concept of biological/chemical similarity as an additional index for assessing the acceptability of transfers.

The complexity and little known response of ecosystems to flow and quality regime changes made the fisheries and aquatic biology groups less willing to define the direction of or criteria for acceptable change, other than by applying principles such as "no deterioration". It was agreed at the workshops that the term "risk" would be used instead of "impact", as a way of emphasising the inherent uncertainty when predicting the response of the aquatic environment.

3.4 Key Issues and Criteria for Environmental Assessment

For the purposes of this high-level assessment of the potential risk of adverse environmental consequences of resource development, key environmental issues have been identified together with criteria for assigning sensitivity and risk to components of water resource developments. This list is a synthesis of the findings of the literature review, information on the actual impacts of existing UK schemes, key concerns raised during the NRA workshop sessions, and the personal knowledge of the consultants working on this study. Key issues and criteria are summarised below by category of impact.

Water Resources

Key adverse impacts in this category concern the derogation of existing abstraction rights in the donor river, and the potential deterioration in water quality in recipient rivers or canals from which water is directly abstracted. Highly sensitive reaches are those with major abstractions for public or industrial water supply; rivers with abstraction predominantly for agricultural or minor industrial use are considered to be of moderate sensitivity. Beneficial impacts may arise through the augmentation of flows in rivers or canals currently exhibiting low flow and/or water quality problems.

General Character/Landscape

At this level of strategic environmental assessment the evaluation of the impact of reservoirs, pipelines or changes arising from alterations to the flow regime of rivers or canals has been based on the landscape designation of the area. High adverse impacts are liable to arise in nationally designated sites, i.e. National Parks, National Heritage Areas, Heritage Coasts, Areas of Outstanding Natural Beauty, National Scenic Areas and National Trust sites. County or local classifications, such as Special Areas of Great Landscape Value, Regional or Country Parks and Green Belt areas, will be subject to moderate impacts.

It should be noted that some reservoirs enhance the surrounding landscape, particularly those which are of a flooded valley type. However, bunded reservoirs such as Staines reservoir have high visual impacts. Visual impact will also depend on the extent of visual envelope and number of receptors affected.

River reaches have been assessed in terms of the naturalness of the reach. Natural reaches are those with no channel works and more-or-less natural flow regime; semi-natural reaches are those which appear to be a natural feature of the landscape but have been depth or flow regulated to some degree; artificial reaches are engineered channels for drainage or land reclamation which retain some natural features or are important landscape features; highly artificial reaches are heavily engineered channels, usually through urban areas, which have lost virtually all conservation interest. It has been assumed that a high risk of environmental impact can only occur in a natural or semi-natural reach.

Water Quality

The water quality of all rivers in the UK is defined by the National Water Council classification, which has been used as the basis for defining both sensitivity and risk. Any development which is liable to result in a fall in quality from Class 1A or 1B, or which breaches the proposed Statutory Water Quality Objectives under Section 83 of the WRA 1991 is assessed as having a high impact. The risk of creating or increasing the frequency of algal blooms or increasing nutrient status is considered to be a moderate impact. A high risk has been assumed whenever water of lower NWC Class is transferred into a watercourse with a higher classification.

Any water quality parameter identified in the scheme-specific environmental assessment as being problematic with respect to statutory limits has been taken to classify the affected components as having a high risk.

Fisheries

The principal impacts relating to fisheries arise from changes in flow, water chemistry and temperature, and the risk of transfer of alien species and diseases. The significance of the impact will depend on the sensitivity and value of the fisheries, and the magnitude of the potential change. High adverse impacts will arise from:

- confusion for homing salmonids from mixing of river waters
- the loss of freshets or spate flows affecting migratory salmonids;
- the physical restriction to movement of migratory species;
- the reduction in flow velocity affecting species with specific flowing water requirements, especially salmonids, chub, dace and barbel;
- a fall in NWC class or exceedence of the threshold level for any EIFAC parameter;
- the transfer of category A pathogens (notifiable diseases) or category B if their incidence in the recipient river is potentially damaging;
- the transfer of alien species;

The following impacts are considered to be moderate in terms of their risk:

- increased duration of velocities outside the species preference;
- fish entrapment (impingement and entrainment) in intakes;
- temperature changes due to mixing or reservoir releases;
- small changes in key water quality parameters for specific species;
- transfer of category C or D pathogens;.

For the present level of assessment, the thresholds of significance for disease transfer have been based on the presence or absence of diseases in the recipient waters. At a more detailed level, the relative incidence of certain diseases will influence the impact acceptability of a water transfer scheme. Fish disease controls are currently under review in order to meet the requirements of the EC Fish Health Directive 91/67 which came into force in January 1993. Current NRA policy with respect to restrictive actions for category B, C and D diseases may therefore be changed in the near future.

Aquatic Ecology

The complexity of aquatic ecosystems, and the lack of precise information about the influence of flows and water quality on the biota, continue to hinder the assessment of aquatic ecological impacts. The conclusions are therefore somewhat subjective although based upon experience of river regulation schemes and based upon clear qualitative guidelines:

- All inter-basin transfers will impact the aquatic ecology of the donor and recipient rivers; this focuses on the questions of impact type and magnitude.

- Because scientific knowledge of ecosystem-level changes of aquatic systems to flow abstraction, regulation and augmentation is far from complete, the naturalness of the rivers affected is considered to be a key variable. Utilization of artificial rivers (with artificially-influenced flows, river levels, water quality and channel form) being preferred for use. This protects 'natural' systems and, for some recipient channels, offers the possibility of enhancing the ecological value of degraded reaches.

- Because of the structure of the drainage network, impacts are assessed at two scales: local and regional. The number of streams of each order declines geometrically with increasing order. A major (local) impact on a 1st-order stream may be only minor significance at the regional scale because there are many 1st order streams within the network. However, a major impact on a 4th order river may be significant locally and regionally because there are relatively few rivers of this size in the region.

- Following points made above, high-order 'natural' reaches are given particularly high value for protection.

- Impacts of hydrological change upon instream habitats depends upon the consequent changes of hydraulic conditions which relates to site-specific channel morphology (slope, width, bedform etc). In the absence of such data, hydraulic thresholds cannot be defined and impacts on specific habitats for rare species cannot be precisely evaluated.

- Ecological quality is assessed by reference to general indices (BMWP, ASPT, the RIVPACS model and subsequent biological banding), again specific community characteristics have not been considered and judgement about impacts is based upon the general principles elaborated in the review section of this report. Biological banding is explained fully in Appendix G.

Other factors taken into consideration in the assessment process include:

- large differences in RIVPACS class between the donor and recipient rivers
- changes in the seasonality of flows
- systematic reduction in flow below the one in ten year dry season flow
- frequency of operation of the transfer scheme greater than once in every ten years if the donor and recipient rivers are of significantly different biochemical status.

The risk of impact is greatest where the affected river or canal system is of high sensitivity, quantified by high BMWP scores, EQI > 1, high number of taxa, high ASPT and classification as biological band A. Moderate risk would be likely to occur in stretches where BMWP scores were moderate, EQI < 1, and the diversity of taxa was limited.

Terrestrial Ecology

A highly significant adverse impact has been taken to arise where sites of international, European or national importance are affected by the scheme, i.e. Ramsar sites, habitats listed in the European Habitats Directive, Special Protection Areas, National Nature Reserves and Sites of Special Scientific Interest. The impacts are also of high significance where a large number of county designated sites are affected, and where the viability of protected, rare or declining species is at risk. High significance has also been accorded impacts on some habitats which cannot be recreated, especially ancient woodland, and the semi-natural habitats of river corridors which, whilst not necessarily afforded statutory designation, form an important part of the resource base.

Impacts of moderate significance are those which affect a very small number of county designated sites or local sites of nature conservation interest.

It should be noted that:

- Some of the above information, particularly on protected species and sites of local or county value, was not available for the study and would need further investigation at a later stage if the options were to be pursued;
- Some river corridors have a high component of semi-natural habitat which, although not designated, still forms an important

part of the resource base. Impacts to such stretches of river may be considered significant;

- Some habitats are more recreatable than others and need further weighting. This particularly applies to Ancient Woodland, the loss of which is unsustainable.

Agricultural Land

Although the increasing efficiency of agricultural procedures and changes in agricultural policy have reduced the priority to retain land in agricultural use (DoE Planning Policy Guidance Note 7), the Note confirms the need to conserve the best land as a long term valuable agricultural resource. MAFF guidelines indicate that a loss of more than 20 ha of grade 1, 2 or 3a land under the Agriculture Land Classification System would be a highly significant impact. Land of lower class is of lesser importance except where particular agricultural practices contribute to the quality of the broad rural environment, as in the Environmentally Sensitive Areas and the three "Tir Cymen" areas in Wales. There is also a need to consider the effects on farm holdings, and farm size and structure.

Archaeology and Cultural Heritage

The DoE PPG Note 16 'Archaeology and Planning' (DoE, 1990) underlines the national importance of many archaeological sites and the need for their protection. Guidance on policies and procedures concerning conservation areas and listed buildings is set out in DoE Circular 8/87. Highly significant impacts are defined as those affecting World Heritage Sites, Scheduled Ancient Monuments and Grade I/II listed buildings, or a large number of other archaeological monuments of local interest. Moderate impacts are defined as those affecting a limited number of "other" archaeological monuments.

Recreation, Amenity and Navigation

Highly sensitive areas in this category include lowland river or canal reaches with statutory navigation, and areas used for contact water sports. The risk of adverse impact is high where rapid fluctuations in flows impede navigation, or where flows are reduced by abstraction to insufficient levels to maintain navigation depth without increased dredging. Water sports are similarly influenced by changes to the flow regime, and where appropriate water quality objectives are breached. An impact on visual amenity is considered to be moderate. Many of the impacts of river transfer schemes may be beneficial in this category, particularly with respect to the augmentation of low flows. Angling is a major activity on most rivers and canals, and the sensitivity and the risk to this activity has been taken to be dependent on the assessed sensitivity and risk to the fisheries.

4. FRAMEWORK FOR ENVIRONMENTAL ASSESSMENT

4.1 Role of Environmental Assessment

Environmental impact assessment (EIA) is the process of identifying, predicting and evaluating the impact of particular activities on the environment, the conclusions of which are used as a tool in decision making. This form of assessment has been applied to the scheme specific studies undertaken by the NRA regions.

The effectiveness of EIA applied at the individual project level is constrained by a number of factors, which are widely discussed in the literature. However one of the principal concerns is that project EIA, as undertaken for the individual development schemes considered by the NRA regions, cannot in itself lead to comprehensive protection of the environment as it reacts to development proposals rather than anticipating them. In general it cannot steer developments towards environmentally resilient locations and rarely addresses alternative proposals.

There is therefore a need for a "higher level" assessment in the planning process, preferably in the early stages. This higher level assessment is likely to take the form of Strategic Environmental Assessment (SEA). SEA may be defined as the systematic and comprehensive process of evaluating the environmental impacts of a policy, plan or programme and its alternatives. It enables relevant environmental issues, objectives and constraints to be more fully involved at an early planning stage and assists in implementing the concept of sustainability.

With the goal of achieving sustainability it seems logical to incorporate environmental assessment into the macro-planning process and encourage optimisation of resource management. The Earth Summit in Rio in June 1992 set out the agenda for action based on the concepts of sustainable development. However, whilst the need for sustainable development appears to be widely accepted, there is confusion as to what the concept means and uncertainty as to how the planner can apply it in the context of development planning and control.

Environmental sustainability has many definitions, but they all include the notion of the continuity of a resource base over time. Sustainable development was defined by Repetto (1986) as a *"strategy that manages all assets, natural resources, and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being."* In the context of the present study, environmental sustainability implies that there is no long-term systematic deterioration in the water environment due to resource development, and equates to the NRA's mission to protect and improve the environment. Since the Brundtland Commission's report in 1987, sustainability has become accepted as a goal of many environmental policies, although in practice its implementation is problematic (Therival et al., 1992). The concept requires an assessment of the carrying capacity of the affected environment, which must not be exceeded if the criterion for sustainability is to be met. From an ecological perspective, however, any calculation of environmental capacity is extremely complex, particularly since the information base is at best incomplete. Appropriate calculations also require estimates of the value of resources, and the extent to which they can be traded-off against development options. But most environmental goods have no market value, and any attempt to place a monetary valuation on them must be based on society's preferences rather than an assessment of their intrinsic value (eg Pearce et al., 1989, Warpenny, 1991).

Notwithstanding these complexities, attempts may be made to identify critical environmental capacities to set sustainability limits for certain environmental parameters. Other components may be identified as less critical, and consideration can be given to their replacement by compensatory actions. SEA recognises this requirement, and may be seen as an integral step in the attainment of sustainability, by broadening the remit of EIA upwards from projects to plans and policies, and defining the acceptable limits of change.

The EC has recently proposed a new Directive for the application of SEA to certain policies, plans and programmes. This was issued in confidence to Member States in early 1991, and is reportedly being opposed by a number of the larger states (Therival et al, 1992) including the UK, where the Department of the Environment, in its first public comment, considered it to be 'premature' (ENDS, May 1991). It now looks likely that no new Directive will be proposed; but instead the legal requirement for SEA may eventually be enacted either through the UNECE Convention on EIA in a trans-boundary context, which encourages the assessment of trans border impacts from policies and plans, or by the amendment of the existing Directive 85/337 to include plans and policies (Local Government International Bureau, 1992).

Notwithstanding the uncertainties surrounding its implementation, Therival et al (1992) report that the proposed Directive is based heavily on Directive 85/337, and consequently the contents of the SEA are not dissimilar from those required for project EIA. The issues to be considered would include the following:

- the main objectives of the policy, plan or programme (PPP);
- how environmental effects were taken into account in formulating the objectives;
- aspects of the environment and the area likely to be affected;
- likely significant effects on the environment of the PPP and main alternatives;
- reasons for choosing the proposed action;
- mitigation measures proposed and adopted for the proposed action, including environmental assessment at subsequent stages;

- compatibility of the proposed action with relevant environmental legislation (EC or national);
- monitoring arrangements;
- an outline of the difficulties encountered in compiling the information;
- a non-technical summary.

The UK has no formal procedure for SEA. The Department of the Environment's guide *Policy Appraisal and the Environment* (1991) presents administrative guidance. The guide recognises that the environmental effects of policy have been overlooked in government policy making. It stresses the need ***to adopt a precautionary approach due to the high level of uncertainty of impact prediction.*** The methodologies proposed are more applicable to the assessment of policies than the plan framework of the present project, in addition considerable emphasis is placed on cost benefit analysis. Planning Policy Guidance note 12 (DoE 1992a) also goes some way to giving guidance on strategic environmental planning.

The application of SEA to this study would lie principally in its ability to identify the least environmentally sustainable schemes, and thus to enable assessment to be concentrated on more environmentally acceptable plan formulations. The initial broad application of a strategic evaluation would also rapidly identify areas where further information is required for the assessment.

There are, however, a number of constraints to SEA at the planning level, including the nebulous nature of the proposals, lack of information regarding projected conditions, lack of precision of impact prediction, and the large number and variety of alternatives. With respect to this project it is important to determine the appropriate level of detail that is required to make meaningful comparisons between the various options.

Strategic environmental assessment is assisted if carried out within a clear policy framework, against which plans and programmes can be considered and implemented. It would be beneficial for the NRA to compile a set of mutually exclusive policy statements relating to each NRA Function, from which it could develop a framework for strategic environmental assessment of water resource development to be used as the basis for determining any proposal for major new resource development or transfer. For example, a policy might be that no new licence to abstract will be granted before leakage control targets are met or that no proposal would be supported which involved the loss of an SSSI. It is strongly recommended that the NRA carry out an SEA of key policies relating to water resource projects.

This study is aimed at an intermediate level of environmental assessment between Strategic Environmental Assessment and the detailed project specific Environmental Impact Assessment, examining all major development options and their components on as comparable and objective a basis as possible, based on readily available information, in order to determine, at a preliminary planning stage, the least environmentally acceptable schemes, further work required to reduce the level of uncertainty over impact prediction, and to identify environmental opportunities and benefits.

4.2 Method of Environmental Assessment

The framework for the environmental assessment is shown as Figure 4.1 and is outlined below (see also Appendix D).

The basic unit of assessment has been taken to be the components which make up the transfer option. The components are defined as:

River reaches	}	in which aquatic issues dominate
Canal reaches	}	
Reservoirs	}	in which general planning issues dominate
Pipelines	}	

The assessment matrices for these two groups of components differ due to the nature of the impacts. A series of assessment tables has been produced for rivers and canals; and likewise a corresponding set of tables for reservoirs and pipelines.

The potential for environmental impacts depends upon: the sensitivity of the site/receptors; the risk of significant environmental change/damage; the expected magnitude and duration of change; and the potential for mitigation. A further important factor to be considered in the assessment is the opportunity for environmental improvement or benefits associated with the scheme.

4.3 Categories and Criteria

The categorisation of impacts and criteria for assessing their severity follows directly from the key issues and criteria identified in Section 3.4. For rivers and canals aquatic issues are most important, and the categories used are water resources, general character of the reach, existing water quality, fisheries status, aquatic ecology, terrestrial ecology, recreation/amenity/navigation, and general land-use/planning issues. For reservoirs and pipelines terrestrial categories are of primary importance; and the categories adopted are general character of the landscape, agricultural land, existing archaeology and cultural heritage, terrestrial ecology, recreation and amenity opportunities, and general land-use/planning issues.

The existing sensitivity of each of these categories may be "high", "moderate" or "low". In general, receptors of national importance or with statutory protection have been deemed to be of high sensitivity, for example a NWC Class 1 river. The criteria for "high" and "moderate"

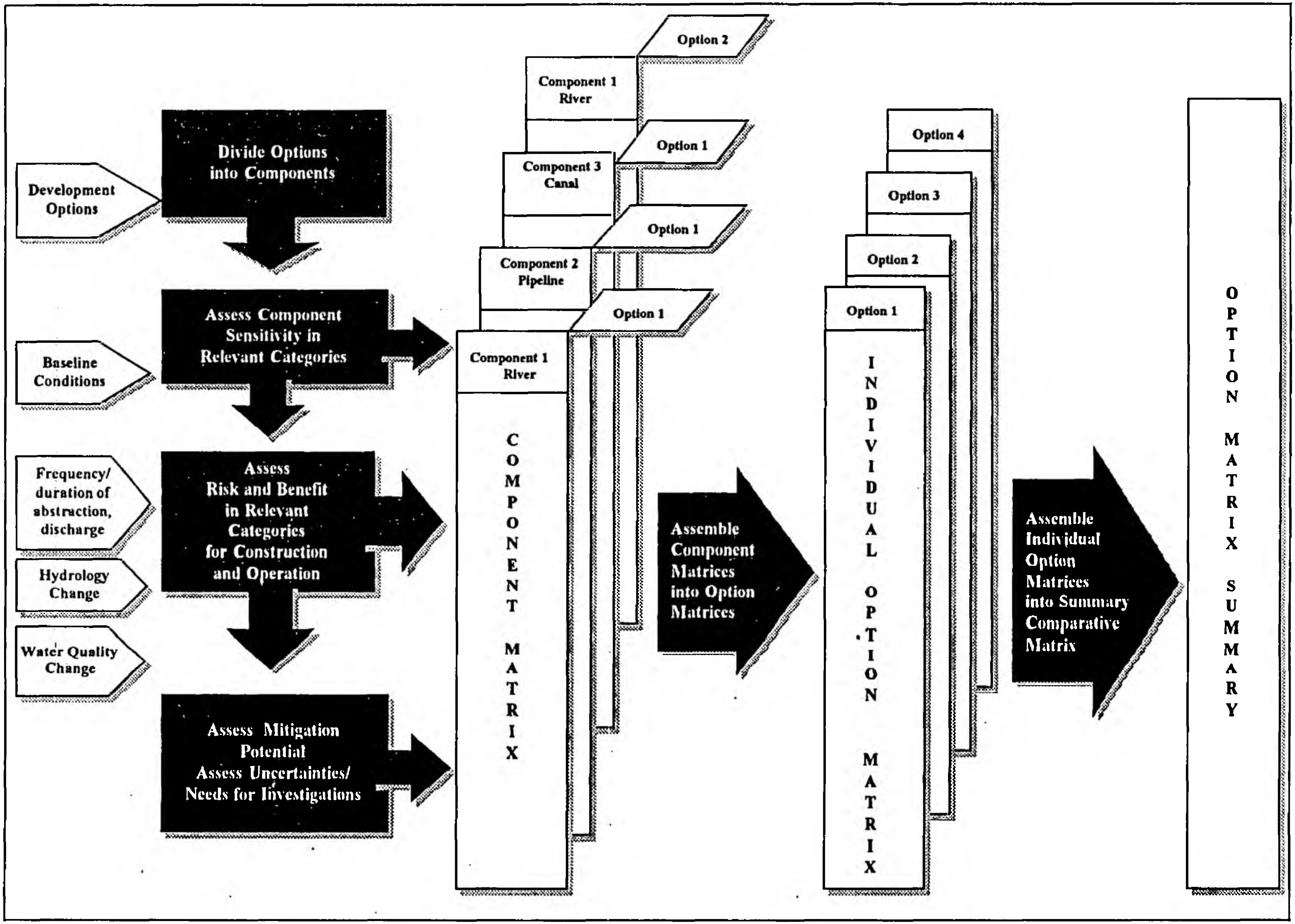


FIGURE 4.1 - ENVIRONMENTAL ASSESSMENT FRAMEWORK

sensitivities defined for use in this assessment are given in Table 4.1 for rivers/canals and Table 4.2 for reservoirs/ pipelines. Whilst these guidelines have been generally followed in the assessment, expert judgement was used to uprate or downrate the sensitivity based on knowledge of particular local circumstances.

The assessment of risk was made in a similar manner. Risk is the potential for significant adverse change or impact consequent upon the scheme, and may be short term (only experienced during construction) or long term (experienced when the scheme is operational). The criteria for "high" and "moderate" risks defined for use in this assessment are given in Table 4.3 for rivers/canals and Table 4.4 for reservoirs/pipelines.

As discussed in Chapter 3, the complexity of aquatic and terrestrial ecological systems is such that the effects of particular impacts on the functioning of these systems is not yet fully understood. It has therefore been particularly difficult to define specific thresholds for these receptors above which impacts can be defined as significant or unsustainable, and assessment has been largely based on professional experience and judgement.

In contrast to most environmental assessments the methodology and criteria that form the basis for assessment have been deliberately made at least partially transparent. The criteria shown in Tables 4.3 and 4.4 are an attempt to be as rigorous and consistent as possible when comparing the effects of quite different components and overall schemes.

In the assessment of risk, it has been assumed that the water transfers will occur as planned and modelled in the individual scheme-specific environmental assessments. Clearly a change in frequency of water transfer could lead to a completely different set of risks which have not been considered in this assessment.

Where specific hydrological data were lacking and with/without scheme details were lacking, a preliminary analysis of hydrological change has been carried out using data extracted from the Institute of Hydrology (1993) Summary of Hydrological Statistics 1986-1990.

4.4 Assessment of Option Components

Each scheme component has been assessed using data from existing reports and option studies. It is reiterated that the criteria are intended as guides only, and expert judgement has been used to uprate or downrate the sensitivity and risk based on knowledge of particular local circumstances. There are a number of variants for each pipeline transfer but only one has been selected for discussion. Assessment of pipelines has been made in principle only, due to the disparate specific issues associated with each pipeline variant.

The results of the assessments have then been drawn together in a summary matrices for every option component, which are included in Appendix D. Examples for reservoir and river reach components are given in Tables 4.5 and 4.6 respectively. A discussion of the major risks and opportunities for each component is given in Chapter 5.

4.5 Comparison of Options

The summary matrices for each development option, drawing together the option component assessments, are presented in Chapter 5. They are a means of presenting the information arising from the assessment and are not in themselves a method of decision making. The overall assessment for each option has been taken to be the sum of its components. The breakdown between short terms construction and long terms operation impacts and between "high" and "moderate" has been retained rather than combine the assessments in an overall index. Benefit opportunities have also been retained in the option matrix. Example matrices are presented in Tables 4.7 and 4.8.

This approach inevitably means that schemes with more components are more likely to appear to have a higher environmental risk. It also effectively gives equal weighting to different categories of impact and criteria, this could be changed as appropriate in future development of the methodology.

The advantages and disadvantages associated with each option are summarised in Chapter 6 on a regional basis. The concept of acceptability is introduced, representing an overall assessment of whether or not an option is environmentally acceptable and could be supported by the NRA. Destruction, loss or permanent damage to important nature conservation sites or fisheries has been deemed to be grounds for the option being unacceptable as far as the NRA are concerned. The *acceptability* or otherwise of schemes from an NRA perspective is difficult for external consultants to judge. A set of clear policy statements relating to each category of impact identified in this report would help this assessment.

Table 4.1 - River/Canal Framework for Assigning Sensitivity

Category	Sensitivity		Benefit
	High	Moderate	
General Character/ Landscape	Semi-natural Unregulated channel	Modified	Potential for enhancing semi-natural and non-natural character
Water Quality	National Water Council (NWC) Class 1 River Water Quality Objective (RQO) - Water supply	NWC Class 2 or 3 RQO - Contact sport	Bring reach into Class Improve NWC Class 4
Fisheries	Salmonids and certain species of coarse fish Commercially important fishery	Flowing water cyprinids	Improve low biomass Improve poor quality fishery
Aquatic Ecology	High Biological Monitoring Working Party (BMWP) scores High Average Score Per Taxa (ASPT)	Moderate BMWP scores EQI = <1 Moderate ASPT	Improve low BMWP score for NWC Class Improve low ASPT
Terrestrial Ecology	Presence of internationally or nationally designated site Numerous regionally or locally designated sites Presence of protected species	Presence of regionally or locally designated site	Increase habitat diversity
Recreation/ Amenity/ Navigation	Statutory navigation Contact water sports	Non-statutory navigation Visual amenity importance	Restore/Improve derelict navigation Improve perceived low flows
General Land-use and Planning Issues	Conflict with existing land-use designations	Reduction in resource value	Potential for enhancement identified in Development Plan

Table 4.2 - Reservoir/Pipeline Framework for Assigning Sensitivity

Category	Sensitivity		Benefit
	High	Moderate	
General Character/ Landscape	Located in or near internationally or nationally designated area	Located in or near regionally or locally designated area	Increase and enhance landscape diversity
Water Quality	Public Water Supply reservoir	Off-line river regulation reservoir	Improve downstream dilution
Agriculture	MAFF Land Class 1, 2, 3a	Land Class 3b	Enhanced land access
Archaeology and Cultural Heritage	Presence of internationally or nationally designated site/monument/ building	Presence of other archaeological artifacts/ sites	Excavation and recording
Terrestrial Ecology	Presence of internationally or nationally designated sites Numerous regionally or locally designated sites Presence of protected species	Presence of regionally or locally designated sites	Increase habitat diversity
Recreation/ Amenity	Presence of National Park or Area of Outstanding Natural Beauty	Presence of significant number of footpaths	Offer recreation potential
General Land-use and Planning Issues	Conflict with existing land-use designations		Potential for enhancement identified in Development Plan

Table 4.3 - River/Canal Framework for Assessing Risk of Significant Impact

Category	High Risk		Moderate Risk		Mitigation
	Key Impact	Criteria	Key Impact	Criteria	
General Character/ Landscape	Reduction of natural character	Alteration of channel	Minor local impact on semi-natural channel or flood plain	Construction works in/ adjacent to channel	Environ-mentally sensitive design
Water Quality	Fall in NWC Class	Transfer of water of lower NWC Class	Increased frequency of algal blooms	Transfer of water of higher nutrient status	Water Treatment
	RQO parameter above threshold level for use	Dilution at Q_{95} of problem determinands	Increased saline intrusion		Setting of prescribed flow .
Fisheries	Loss of freshets/ spates for migratory salmonids	Inspection of with/without annual hydrographs	Increased duration of velocities outside species preference	Outside natural variation of low flows	Use of artificial freshets
	Change in spawning grounds	Reduction in Q_{95} or MAM7 no worse than 1:10 drought	Fish entrapment on intakes		Spate sparing Use of fish screens and design of intakes
	Change in nursery grounds	Flow increase beyond natural variation	Temperature changes due to mixing or reservoir releases	Dissimilarity of temperature and water quality dilution and frequency	Fisheries management policy
	Change in river "smell" for migrating fish	Similarity of donor/ recipient rivers and mass balance calcs.			Variable depth of reservoir draw-off
	Reduction in low flow/velocity	Flow reduction beyond natural variation			Treatment of transfer water
	Fall in NWC Class or exceedence of threshold level for EIFAC parameter				
	Transfer of species	Presence/ absence of species	Small changes to key water quality parameters (species dependent)	Risk to species	
	Transfer of pathogens (A and B categories)	Presence/ absence of diseases	Transfer of pathogens (C and D categories)	Presence/ absence of diseases	

Table 4.3 (Cont'd)

Category	High Risk		Moderate Risk		Mitigation
	Key Impact	Criteria	Key Impact	Criteria	
Aquatic Ecology	Significant changes to macrophyte population Significant changes to macro-invertebrate population structure classified as Class A or of regional importance	Similarity of donor/ recipient water quality and dilution Frequency of operation (<1:5) Change in flow seasonality or variability from inspection of hydrographs Reduction in low flows (MAM7 or Q_{95} <1:10 drought values) Large difference of RIVPACS class	Moderate changes to macrophyte population Minor changes to macro- invertebrate population, or high changes to poor quality stretches (Class C and D)	Similarity of donor/recipient water quality and dilution Frequency of operation (>1:10) Small difference in RIVPACS class	Water treatment
Terrestrial Ecology	Impact to or loss of nationally/ internationally designated site	Presence/ absence of sites and large change in flow regime through highly sensitive site	Impact to or loss of regionally or locally designated sites	Presence/ absence of sites and change in seasonality or variability of flow beyond natural range	Environ-mentally sensitive design of engineering works
Recreation /Amenity Navigation	Increased frequency of dredging Impact on quality of angling Loss of sports to floods Increased frequency of failure to maintain navigable depth Fall in RQO parameter for reach (covered under water quality)	Inspection of annual hydrographs for absence of or reduction to flushing flows Reduction in low flows below threshold to maintain navigable depth	Reduction in visual amenity	Expert opinion	Use of artificial spates Setting of prescribed flows

Table 4.3 (Cont'd)

Category	High Risk		Moderate Risk		Mitigation
	Key Impact	Criteria	Key Impact	Criteria	
General Land-use and Planning Issues	Prejudicing potential/planned land-use	Conflict with Development Plan		Partial conflict with Development Plan	Consultation and possibly compensation

Table 4.4 - Reservoir/Pipeline Framework for Assessing Risk of Significant Impact

Category	High Risk		Moderate Risk		Mitigation
	Key Impact	Criteria	Key Impact	Criteria	
General Character/ Landscape	Effect on internationally or nationally designated area	Permanent change to existing views	Effect on internationally or national designated area Effects on regionally or locally designated area	Temporary change to existing views Permanent change to existing views	Planned increase of visual diversity
Water Quality	Significant algal problems in reservoir or risk of exceeding threshold of parameter for public water supply use	Source and Strophic Status of stored/ transferred water	Anaerobic conditions in pipeline	Distance and frequency of operation	Water treatment Operational control rules
Agriculture	Significant loss of MAFF Class 1, 2 or 3a land	≥ 20 ha permanently lost	Major loss of Class 1, 2 or 3a land Temporary loss of Class 1, 2 or 3a land Significant loss of Class 3b land	< 20 ha loss ≥ 20 ha loss	Provision of compensation supplies
Archaeology and Cultural Heritage	Effect on international or nationally designated site/monument/ building Effect on other archaeological monuments	Destruction or damage to site/ monument/ building Destruction or damage to setting Cumulative damage to a significant number of sites	Effect on a limited number of other archaeological monuments	Destruction or damage to monument	Funded archaeological survey before development

Table 4.4 (Cont'd)

Category	High Risk		Moderate Risk		Mitigation
	Key Impact	Criteria	Key Impact	Criteria	
Terrestrial Ecology	Effects on internationally designated site	Permanent destruction or damage	Effects on internationally or nationally designated site	Temporary destruction or damage	Habitat creation, revegetation
	Effects on nationally designated site	Permanent destruction or damage	Effects on regionally or locally designated site	Permanent destruction or damage	
	Effects on regionally designated sites	Cumulative damage to a number of sites			
	Effects on protected species	Loss of population or decrease in viability of population			
Recreation/ Amenity	Effect on National Park or Area of Outstanding Natural Beauty	Impairment of aesthetic enjoyment	Footpath loss Footpath diversions of over 500m	Unmitigable or significant loss of footpaths	Creation of recreation/ amenity facilities
General Land-use and Planning Issues	Prejudicing potential/planned land-use	Conflict with Development Plan		Partial conflict with Development Plan	Consultation and possibly compensation

5 ENVIRONMENTAL IMPLICATIONS OF STRATEGIC OPTIONS

5.1 OPTION 1: Unsupported Severn-Thames Transfer

Description

This option was studied in detail by WS Atkins (1993). Additional work relating to this option was also undertaken by Howard Humphreys and Cobham Resource Consultants (1992). The engineering works involved are:

- Intake works on the River Severn at Deerhurst;
- Bankside storage at Deerhurst (1200Ml bunded reservoir);
- Highlift pump station at Deerhurst;
- 1.4m diameter pipeline approximately 60km long (Route 3 in Atkins report);
- Discharge structures at pipeline outlet into gravel pits at Down Ampney, and at the discharge into the Thames at Eysey Lock;
- Restoration of the Thames & Severn Canal from Eysey Lock to Inglesham Lock at the Thames/Coln confluence near Buscot.

Assumptions:

- Maximum transfer capacity 400 Ml/d;
- Prescribed Flow in River Severn at Haw Bridge 2500 Ml/d; this is a very preliminary proposal and a great deal of further work is required to assess the PF;
- No Abingdon Reservoir.

The summary environmental for this option is shown in Table 5.1, while assessments for each component are presented in Appendix D.

5.1.1 River Severn Downstream of Deerhurst

This component includes the local impacts associated with the intake and the impacts on the reach downstream to the estuary. Table 5.1 summarises the environmental assessment.

General Character

The proposed intake is downstream of the Avon confluence and 4 km upstream of the gauging station at Haw Bridge with a catchment area of 9895 km^2. The catchment is already heavily regulated by reservoir releases and the Shropshire groundwater scheme. The channel is semi-natural downstream and an important feature of the landscape.

TABLE 5.1 Option 1 Environmental Assessment

OPTION 1. Unsupported Severn – Thames Transfer
TRANSFER: 400 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
1.1	Pipeline: Deerhurst to Down Ampney	High	Moderate	Moderate	High	High	Moderate	Low	Low	Low	Low	Low	Low						

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
1.2	Unsupported R.Severn d/s Deerhurst	Moderate	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low	Low						
1.3	Pipeline: Deerhurst to Down Ampney	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low						
1.4	Gravel Pits at Down Ampney																		
1.5	Thames & Severn Canal	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low		Moderate	Moderate	Moderate	High	Low
1.6	R.Thames at Buscot	Low	Low	Low	Low	Low	Low	High	Moderate	Low	Low	Low	Low		Low	Low		Moderate	Low

RISK/OPPORTUNITY KEY:

- HIGH (black)
- MODERATE (dark shading)
- LOW (light shading)
- NOT APPLICABLE (white)

CATEGORY KEY:

WQ	=	WATER QUALITY
F	=	FISHERIES
AE	=	AQUATIC ECOLOGY
TE	=	TERRESTRIAL ECOLOGY
RAN	=	RECREATION/AMENITY/NAVIGATION
OTH	=	OTHER GENERAL PLANNING ISSUES
Ag	=	AGRICULTURE
Com	=	COMMUNITY IMPACTS
Arch	=	ARCHAEOLOGY & CULTURAL HERITAGE
GLC	=	GENERAL LANDSCAPE CHARACTER

Hydrology

At this location, the Severn is tidal with high sediment loads and a depth-velocity regime dominated by the tidal cycle. The proposed intake is considered to be upstream of saline intrusion even under pessimistic sea-level rise scenarios (WS Atkins 1993).

The present mean flow (MF) is 9098 Ml/d and the Q_{95} low flow is 1766 Ml/d. The minimum recorded mean daily flow was 1061 Ml/d in August 1976. The mean annual flood is greater than 40000 Ml/d.

With a maximum abstraction rate of 400 Ml/d and a PF of 2500 Ml/d, the potential resource value of this option without the Abingdon Reservoir is 146 Ml/d (NRA Thames Region 1993). Hydrological simulation studies indicate a frequency of operation of about once every 3 years (27 out of 72 years), for an average of 83 days/year.

The very preliminary PF being considered is greater than Q_{95} flow, and hence the low flow regime would be protected. The proposed peak rate abstraction would have an insignificant effect on the mean flow to the estuary and high flow regimes (less than 5%). The maximum reduction in discharge of 14% would occur at flows just above the PF. The steep recession curve in the flow range 2500-4000 Ml/d means that the effect of the abstraction would be to increase the duration of flows of 4000 Ml/d by between 0 to 10 days during the August to December period which is critical for salmon runs.

Water Resources

The only significant abstraction downstream of Deerhurst is to the Sharpness Canal supplying BWB and Bristol Waterworks Company. Provided the PF is above 2500 Ml/d, the canal intake should not be affected. Any effects on minor agricultural abstractions are also considered negligible.

Water Quality

The River Severn at Haw Bridge achieves its RQO of NWC Class 1B. The reach downstream of the River Chelt is now set at Class 2. With a PF above the Q_{95} flow, there is little risk of causing significant changes in quality downstream of the intake.

The Severn Estuary is Class B, due to effluent discharges from large towns along the estuary. The proposed abstraction should not cause any significant reduction to estuary dilution and flushing flows with the PF of 2,500 Ml/d.

Fisheries

This tidal river is wide (60-90m), moderately deep (2.5-4.0m) and largely devoid of marginal macrophytes. In many cases the banks support willow and alder growth. Saline intrusion does not reach Gloucester Weir, which is about 10km downstream.

Coarse fish present are typical of a lowland river and include roach, bream, gudgeon, pike, zander, barbel, carp, eel, perch, chub, dace, shad, minnow and bleak. Salmon, sea and brown trout also occur, along with flounder and mullet, but these are only to be found at low numbers.

It is currently believed there are only four rivers in the UK with breeding stocks of twaite shad (Severn, Wye, Usk and Tywi). The Severn stock is the largest, and Deerhurst is near the epicentre of the spawning activity. Shad enjoy a high conservation interest at present, and measures would be required to avoid entrapment of fry and juveniles at the intake.

Quantitative assessment of the fish stocks downstream of Deerhurst has been attempted by the Severn Trent NRA/Severn Trent Water Authority and reveal a low numerical and biomass density of fish (about 0.01-0.5 fish m^2 0.8-2.1g/m^2), but these results must be evaluated with caution due to the inherent bias of estimating fish stock from electrofishing and echo sounding techniques. Match anglers on this stretch tend to either concentrate on catching lots of the small sized bleak or one of the larger barbel. Pleasure anglers may find bream. The number of anglers fishing this stretch is low compared to upstream areas or the nearby River Avon.

The growth rates of fish are low, probably due to the low number of high quality weed and associated invertebrates, and to a lack of instream fauna inhibited by the poor substrate stability.

Flows in the River Severn downstream of Deerhurst would be reduced by 400 ml/d, subject to the proposed prescribed flow of 2500 ml/d at Haw Bridge. This PF represents 27% of present mean flow and 140% of the Q_{95} flow in the lower Severn.

Baxter (1961) and Tennant (1972) have suggested that salmonid migration becomes adversely affected at flows below 30% of annual mean flow. Recent tracking studies in South Wales (Clarke pers comm) have suggested reduced probability of migration into freshwater reaches when flows fall to less than 80% of average dry weather flow. Work reported by Frake and Solomon (1990) showed reduced tendency for upstream migration in the Hampshire Avon below flow levels equivalent to 60-80% of mean flow.

The above studies were in rivers much smaller than the Severn, but clearly demonstrate that negative migratory responses can be shown with declining flow at almost any level from mean flow downwards. The studies relate to effects observed during summer low flow periods and to some extent may reflect the natural seasonality of events and responsiveness of fish.

The above studies provide no consistent guidelines for a river as large as the Severn, but nevertheless, indicate that salmonid migration is likely to be an issue requiring site specific investigation. As the abstracted volume is small in relation to the mean and prescribed flows, effects on salmonids are likely to be small in relation to the natural range of flows and migratory responses.

Aquatic Ecology

Aquatic invertebrate data are only available up until the early to mid 1980s as biological sampling below Worcester has ceased due to sampling difficulties and the nature of the substrate. In general the aquatic ecology of the lower Severn is impoverished. BMWP scores ranged from 3 in July 1976 to 47 in April 1982. In 1976-77 surveys carried out showed a very low diversity and abundance, reaching their lowest level in 1976 when only three organisms were recovered from over 100 dredge samples. Poor quality results from the fact that the sampling sites near and downstream of Deerhurst, ie Haw Bridge, Ashleworth and Maisemore Lane, have little bankside vegetation, the margins being predominantly of heavy clay and the central channel of solid clay.

A sampling programme implemented as part of the Central Water Planning Unit (CWPU) studies (1980) compared the Severn and Thames invertebrates and revealed two amphipod species *(Gammarus zaddachi and G tigrinus)* in the lower Severn that were not present in the River Thames. These two species are common to brackish water and their transfer is not considered a threat to the Thames ecology.

The proposed abstraction is unlikely to have any adverse effects on instream ecology downstream of Deerhurst.

Terrestrial Ecology

There are a number of wetland sites downstream of Deerhurst. Ashleworth Ham SSSI (SO833263) is located just downstream and comprises a large area of grassland overlying alluvial soils in the Severn floodplain. Parts of the site are of botanical interest while the whole area which floods each year is an important refuge for wintering wildfowl and is one of the three remaining such sites in the Severn Vale.

Coombe Hill Canal SSSI adjacent to Deerhurst is a disused canal adjoining the River Severn supporting a rich aquatic flora. Of particular interest are the alluvial meadows on either side with their characteristic flora. In winter these flooded meadows are attractive to wildfowl.

Much further downstream is Walmore Common SSSI (SO740162 and SO745150) which is a low-lying area in the Severn Vale subject to annual winter flooding. In addition to being of botanical interest the site is an important refuge and feeding area for wildfowl. Walmore Common is also a Ramsar Site i.e. a wetland site of international importance, through regularly supporting 170 Bewick's Swans *Cygnus columbiarius* (1% of the number wintering in NW Europe).

It is understood that the proposed abstraction would not reduce winter flooding on any of the sites of nature conservation value and therefore they should remain unaffected. However, this would need to be explored more fully at a detailed evaluation stage.

Recreation/Navigation/Amenity

The lower Severn is navigable up to Stourport-on-Severn and is used by canoeists. With a proposed PF of around 2500 Ml/d, there are not expected to be any adverse effects from abstraction.

Summary

Provided the abstraction is limited to 400 Ml/d and a PF is set at around 2500 Ml/d, then abstraction is a small proportion of the mean flow regime and the low flow regime is protected. There do not appear to be any significant environmental risks associated with this component. With further upstream developments in the Severn catchment, there may be cumulative effects which tend to increase the duration of low to medium flows above the PF and lead to an overall reduction in quality. A PF of 2500 Ml/d may not be sufficient for salmon migratory responses, and further studies are required to determine the PF required to protect all downstream interests. All future developments in the catchment should be assessed in an integrated way.

5.1.2 Bankside Storage and Pumping Station at Deerhurst

Outline design for this component is included in a report by WS Atkins (1993). The main purpose of bankside storage is to meet water quality criteria and reduce the sediment load transferred along the pipeline. The reservoir would need to be provided with a spillway which would discharge south into the Coombe Hill Canal area which is a wetland SSSI.

General Planning Context

Siting of the reservoir will need to take into account possible effects on flood plain storage, and on levels of service for flood defence schemes upstream and downstream.

Detailed attention would have to be given to minimising visual impact through appropriate design and landscaping, particularly as regards views from Deerhurst Village. The Site and Monuments Record (SMR) indicates a high level of archaeological interest in the Deerhurst area. Three Scheduled Ancient Monuments are present in or close to the village and a full archaeological survey is recommended. With the level of detail currently available, it is not possible to be more precise about specific development impacts.

Land-take at Deerhurst would affect agricultural land of good quality in the river valley, and affects on farm viability would need to be evaluated. The river Severn at Deerhurst has public footpaths along both banks and there is a complex network of footpaths and bridleways in the vicinity. A golf course lies approximately 1 mile north east of Deerhurst and enjoys views over the river. Construction, location and design of any structure would need to take account of these. Storage should avoid any sites of nature conservation importance.

5.1.3 Pipeline, Deerhurst to Down Ampney

Water Quality

It has been estimated that the travel time for water in the pipeline would be about 10 hours and it is not anticipated that there will be problems of anaerobic conditions developing. However, during long periods of the year, and sometimes for years at a time, there would be no transfer, and it is important that careful consideration be given to how the pipeline is drained and the water discharged. It has been suggested that draw down of the pipeline by pumping to the Thames would avoid any problems. Other potential quality risks associated with the pipeline are out-gassing, scaling and corrosion. However, these problems are common to many water pipelines and can be overcome by careful design.

General Planning Context

This route crosses the River Swillgate and skirts north and west of Cheltenham below the scarp slope of the Cotswolds into the River Churn Valley to Down Ampney.

Potential impacts would be largely temporary and confined to the construction phase. Good environmental practice would need to be observed during construction with appropriate landscaping and restoration being essential, especially as this scheme traverses the Cotswold Area of Outstanding Natural Beauty (AONB). There are a number of nature conservation constraints along this route corridor that would require route amendments, especially woodland sites along the Churn Valley and areas of damp pasture.

The Sites and Monuments Record (SMR) indicates high archaeological interest in the area and further evaluation would be needed prior to construction.

The ALC Map Grades of soils along the route are generally 3 and 4,with small areas of Grades 1 and 2 on the Thames river terraces at Down Ampney and along the route of the Thames and Severn Canal.

Summary

Although there are moderate water quality risks associated with intermittent pipeline transfers, these are well understood and could be overcome by appropriate feasibility studies and careful design. The impacts associated with infrastructure should be mitigable through careful planning, and design and construction. Detailed field work and consultation would be needed prior to construction.

5.1.4 Gravel Pit Storage at Down Ampney

Water Quality

There are concerns that groundwater pollution associated with Fairford Airfield might be a problem if the gravel pits were developed. Groundwater investigations and modelling studies would be required to investigate this potential problem.

The high suspended sediment loads in the Severn would have to be dealt with to avoid frequent dredging.

General Planning Context

An area near Down Ampney is identified for gravel abstraction in the Gloucestershire Mineral Plan, although extraction may not be completed until 2002 or later. The exhausted gravel pits could be used as a water storage reservoir, although it has been stipulated by the planning authority and the Ministry of Agriculture Fisheries and Food (MAFF) that the preferred after-use is to agriculture. Restoration of water is often looked upon as a significant positive impact of mineral extraction. However, at Down Ampney, which lies between two areas of water park, this could be regarded as an undesirable impact. The soils on the site at Down Ampney are Grade 2 to the north-west and Grade 3 to the south-east. Farming here is a mixed arable livestock system of high standard. The overall impact on agriculture would be moderate to high.

The SMR indicates high archaeological interest in much of the upper Thames area and detailed surveys would be required. There are also sites of local conservation value near to Down Ampney that would need further research.

Recreational benefits can accrue from the use of gravel pits for water storage, although planning policies are more likely to control uses, due to the extent of water based recreation already available at Cotswold Water Park.

Summary

This component would involve significant loss of agricultural land, and may not be the preferred after use of the site. Careful planning and operation of the gravel pit extraction would ensure the creation of the optimum storage facility and minimise additional works. Groundwater could be excluded by appropriate design measures if there is a pollution risk.

5.1.5 Restored Thames & Severn Canal

General Character

The Thames & Severn Canal is presently derelict, and hence there are considerable potential benefits through sympathetic restoration. The canal is partly within the Cotswold Area of Outstanding Natural Beauty (AONB), and any engineering works would have to meet strict planning requirements.

Hydrology

The restored canal would have to accommodate the full peak flow rate of 400 Ml/d, which could be accommodated with an additional freeboard of 0.4m at Eysey Lock. Flow velocities would be typical for a navigable canal (less than 0.3m/s) and are not anticipated to be a problem.

Water Resources

With the transfer only used once every three years on average, then an additional resource would be required to maintain a sweetening flow and for losses and lockage, if the canal were used regularly for navigation. Up to 7 Ml/d would be required, either from Down Ampney gravel pits or by developing a new borehole supply.

Water Quality

Severn water is now Class 1B and has shown steady improvement over the past two decades. Some mixing with local and surface groundwater may occur in the gravel pits, depending on the design. As discussed in Section 5.2.2, it would be important to minimise sediment loads so as to minimise dredging requirements.

Fisheries/Aquatic Ecology

Restoration of the canal could provide both nature conservation and fisheries opportunities. Restoration of the Thames and Severn Canal would enhance visual and recreational amenities. However, due to the limited size of the canal and intermittent nature of transfer flows, with velocities increasing to 0.3m/s in late summer, the canal is not expected to produce a stable or extensive coarse fishery.

Terrestrial Ecology

The line of the old canal should be surveyed prior to construction and any localised areas of ecological value or protected species should be avoided if possible.

Recreation/Amenity/Navigation

Restoration of the canal would offer important benefits for both recreation, amenity and navigation. Restoration of the canal from Inglesham Lock to the Cotswold Water Park could have significant benefits for tourism.

General Land Use and Planning

The district council local plans specifically preclude development along the canal route so as to encourage renovation, and proposals to renovate the canal would have the support of both the Local Authorities and the Cotswold Canals Trust. During renovation there would be moderate impacts associated with the engineering works and care would need to be taken with disposal of dredged material. Land take would be approximately 17ha, the majority of which is under arable farming. Although high quality land, the amount of landtake is less than 20ha and therefore the impact is considered low.

Summary

This component offers considerable conservation and recreation benefits and no unmitigable risks.

5.1.6 River Thames, Buscot to Egham Reach

General Character

The Thames at Buscot is a regulated semi-natural channel at an elevation of about 70m AOD and a catchment area of 997 km^2. The discharge from the Thames & Severn Canal at Inglesham is just downstream of the confluence of the Thames with the River Coln. The river and tributaries upstream are typical chalk upland watercourses with well developed pool-riffle structures, but downstream of Buscot the Thames has historically been depth regulated for navigation. The upper Thames catchment is being proposed as an Environmentally Sensitive Area (ESA).

Hydrology

There is a gauging station on the Thames at Buscot. The MF is 816 Ml/d and the Q_{95} low flow is 97 Ml/d. The minimum recorded daily flow was 72 Ml/d in August 1990. MAF is greater than 3500 Ml/d. Depth regulation means that changes in low to moderate flows tend to cause a corresponding increase in velocity rather than depth.

Hydrological analysis presented in WS Atkins (1993) and by NRA Thames Region (1993) indicates that transfers would tend to occur between September to December and might last for more than a month. The peak transfer rate of 400 Ml/d would significantly increase discharge and velocities during low flow months, with discharge up to 4 x Q_{95} although these would remain within the natural range of variation for the channel. There would be a change in seasonality, particularly of late summer August/September flows, which would be maintained at flows typical of November/December. Whilst this would alleviate low flows in the upper Thames, the magnitude of the transfer is clearly of concern.

In dry years, the low flow regime would become dominated by Severn water which would be **4 times** more than the quantity of Thames's baseflow. These impacts would reduce downstream, although even at Days Weir downstream of Oxford (catchment area 3445 km^2) the transfer would still exceed 50% of the Q_{95} low flow.

Water Quality

The differences between the water quality of the Severn at Deerhurst and the Thames at Buscot are also important in assessing the impacts of the transfer. The transfer would occur with a frequency of around once every three years and could last for months at a time during the months of lowest natural flows in the Thames.

The abstraction point on the Severn is at the downstream limit of a large varied catchment with contributions from upland limestone catchments in mid-Wales, groundwater from Drift and Triassic sandstone and sewage and industrial effluent from large urban conurbations such as Coventry, Rugby and Cheltenham. The Thames at Buscot in contrast has a rural upland catchment with a low flow regime dominated by calcareous groundwater baseflow. Thus, despite the superficial similarity of their NWC Class 1B, the abstraction and discharge points represent completely dissimilar water quality and aquatic environments. The frequency and magnitude of the potential transfers into the Thames are such that there is a risk of causing a significant change to the chemistry of the upper Thames.

There are significant differences between the donor and recipient waters for all parameters other than temperature and reactive silica. Of particular concern are chlorides in the Severn which are double the concentration in the Thames, while there are lower TON and nitrates in the Severn, higher phosphates and Severn alkalinity is half the concentration of upper Thames water. The consequences of these changes is difficult to predict, but must be assessed as of high risk.

Fisheries

The Thames fisheries are typical of a lowland watercourse. Fisheries survey results (NRA) indicate that populations in the middle and upper reaches are dominated by roach with bleak, gudgeon with smaller numbers of perch, chub, dale, bream and pike. Cray fish and lamprey are among other species observed in the middle and upper reaches. For much of its length the River Thames is designated as a Cyprinid Fishery Water (EC Directive 78/659/EEC) and as such has a target biomass of $20g/m^2$. Data indicates biomass calculations between $10\text{-}90g/m^2$ for sites in the middle and upper reaches. Local variability is introduced according to habitat type and proximity to major tributaries which provide vital recruitment into the main river.

The river is extensively used for angling and in particular venues such as Medley (Port Meadow) has a national reputation for match fishing. It should be noted that fisheries surveys (RHBNC 1992) have identified the important status of shallow, macrophyte-rich riffle features in the Thames system, particularly as regards fry communities.

Peak transfers would occur during low flow months and while remaining within the natural range of variation for the channel would produce flows and velocities up to five times greater than the catchment. There are likely to be chemical changes due to the different nature of the Severn water. However, the habitat should remain essentially favourable for the range of coarse fish species present and impacts are, therefore, likely to be moderate. There will be positive local benefits in terms of increased dilution of water, which is occasionally of poor quality in the sections immediately upstream of Lechlade.

Aquatic Ecology

The Thames supports diverse macroinvertebrate communities, although as with most rivers the biological quality of the river varies along its length depends on a number of factors. In reaches upstream of the navigable limit at Lechlade the Thames displays a diverse channel morphology. Deep pools are interspersed by gravel shallows overlying the Oxford clay. The area supports good macrophyte communities and invertebrate populations.

Data from the Thames National Data base (1990) at Buscot (SU22909810) indicates excellent quality with a Biological Monitoring Working Party scores (BMWP 1978) of 212 and a diverse range of taxa (40). The Average Score Per Taxa (ASPT) which can minimise error introduced by seasonality and variable sample size is 5.3, again representing a good invertebrate community. The observed BMWP score and number of taxa are in excess of those predicted by the RIVPACS model. Overall the biological class or banding based on the Ecological Quality Index (EQI) is A. Further downstream at the Trout Inn, Godstow biological quality is still high with a BMWP score of 227 and an ASPT of 5.5.

It should be noted that most of the recipient reach is moderately regulated for boat traffic; it is ponded by weirs and locks and is dredged periodically. From an ecological perspective it is less important than other headwater reaches of the Thames, such as the Kennet, which are important Chalk streams. Much of the aquatic interest is likely to be associated with the river margins especially where macrophyte beds occur. Increased flows during low flow years may be beneficial if they reduce the frequency of channel maintenance to maintain depths for boat traffic.

Impacts of the different water quality of the transferred water upon the ecology of this reach are likely to be moderate but most could be mitigated with appropriate management, for example, to maintain oxygen levels in the transferred water and to prevent transfer of suspended sediment loads during floods. However, given the frequency and duration of operation, and the existence of unaffected, good quality tributaries, impacts upon the aquatic ecology are likely to be short-lived and recovery, by downstream drift from the tributaries and reaches above the transfer, relatively rapid. The RIVPACS classification based on taxa present in the lower Severn and upper Thames, show that they support relatively similar communities.

Terrestrial Ecology

There are a number of SSSIs and other sites of county value downstream of Buscot, however, they would be unaffected by the transfer.

Recreation/Amenity/Navigation

Increasing the low flows in the upper Thames is likely to have a negligible impact on any amenity/recreation uses of the river, except if this were considered to be beneficial/detrimental to the quality of angling. The water quality risks associated with the transfer make this a moderate negative impact. Velocities would need to be kept below that which would affect upstream movement of pleasure craft.

Summary

All inter-basin transfers will impact on the aquatic ecology and fisheries of the donor and recipient river to some extent. The frequency and magnitude of the proposed transfers compared to the existing low flow regime at Buscot (4 x Q_{95}) are of concern although flows and velocities would be within the natural variation of this reach. Significant water quality changes would arise when the flow is dominated by Severn water.

The subtle effects of changes in water chemistry on instream ecology fisheries needs further consideration.

5.2 OPTION 2: Craig Goch Regulation of Severn

Description

This option was examined in the Other Options report by Halcrow (1993). This option was included as one of the main options in the study when it became apparent that the resource value of the unsupported Severn-Thames transfer was limited and the unit cost of water from the enlarged reservoir was relatively low. For this reason, there is no separate option study report and assessment has had to be based on the Halcrow's report, on the reports prepared for the Water Resources Board studies between 1972 and 1980 and on primary data from the Countryside Council for Wales (CCW). The option considered here is the smallest reservoir size, fed only by natural runoff from its own catchment. The engineering works involved are:

- New earthfill dam, downstream of existing dam, to a height of 86m and a top water level (TWL) = 366m AOD;
- Temporary and permanent road diversions;
- Tunnel aqueduct from Craig Goch to Llanidloes;
- Potential intake for Severn-Trent transfer at Coalport (see Option 6 for details - maximum abstraction 200 Ml/d);
- Intake for Severn-Thames transfer at Deerhurst (see Option 1 for details - maximum abstraction 400Ml/d).
- Severn-Thames Transfer Scheme (see Option 1 for details)

Assumptions:

- Scheme operated on a put and take basis, i.e., regulation matches abstraction;
- Maximum regulation of River Severn 600 Ml/d;
- Maximum Severn-Trent transfer capacity 200 Ml/d;
- Maximum Severn-Thames transfer capacity 400 Ml/d;
- Prescribed Flow in River Severn at Haw Bridge 2500 Ml/d;
- No Abingdon Reservoir.

The summary environmental assessment for this option is shown in Table 5.2, while assessment for each component are presented in Appendix D.

5.2.1 Enlarged Craig Goch Reservoir

Water Quality

With the enlarged reservoir filling from its natural catchment, there are not considered to be any long term adverse water quality implications from raising the reservoir. Truesdale (1974) recommended that

TABLE 5.2 Option 2 Environmental Assessment

OPTION 2. Craig Goch Enlargement & Severn Regulation
REGULATION: 600 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
2.1	Enlarged Craig Goch	Low	Low	Moderate	Moderate	High	Moderate	Low	Low	Moderate	Moderate	High	Low	Low	Low	Low	Low	Low	Moderate
2.2	Pipeline: Deerhurst to Down Ampney	High	Moderate	Moderate	High	High	Moderate	Low	Low	Low	Low	Low	Low						

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
2.3	R.Severn Llanidloes to Coalport	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	High	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low
2.4	R.Severn Coalport to Deerhurst	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	Low	Low	Low	Low	Low
2.5	Pipeline: Deerhurst to Down Ampney	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low						
2.6	Gravel Pits at Down Ampney																		
2.7	Thames & Severn Canal	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low		Moderate	Moderate	Moderate	High	Low
2.8	R.Thames at Buscot	Low	Low	Low	Low	Low	Low	High	High	Low	Low	Low	Low		Low	Low		Moderate	Low

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

precautions should be taken to limit runoff of fertiliser into the reservoir and the consequent eutrophication risks through consultations with the Forestry Commission and other forestry interests.

Land Use

Existing land use around the reservoir largely comprises Grade 5 agricultural land of very poor quality. However, in the context of the area, they represent the most valuable winter grazing for the tenant farmers. Three occupied farmhouses and associated outbuildings, one unoccupied farmhouse and numerous public footpaths would be lost to the development. They are all tenant land holdings. Numerous other holdings would be affected by flooding although not more than five are likely to be reduced in area by more than 20%. Approximately 500-600 hectares would be inundated in total.

Archaeology

There are no Scheduled Ancient Monuments or listed buildings in the area. Approximately 29 sites of archaeological interest could be inundated, although detailed evaluation may reveal more sites or artifacts of interest. Sites/artifacts include stone structures, old buildings, tracks, pillow mounds, field boundaries, flints (prehistoric), cairns, circular depressions and sections of peat. Impacts on the archaeological interest of the area are considered moderate.

Landscape

The site is not located in an AONB, it is however afforded a local landscape designation, Western Upland Special Landscape Area. Enlargement is unlikely to have significant adverse effects on existing landscape quality although this would depend on the type of dam selected for construction.

Terrestrial Ecology

The most significant implications arising from this scheme are likely to be nature conservation issues. A number of sites of national importance may be affected by the proposed scheme. Elenydd SSSI surrounds Craig Goch Reservoir, extending over 22,770 hectares. It is one of the most important hill land sites in Wales for nature conservation. It is of outstanding interest for its range of breeding birds of upland and woodland. Much of the hill vegetation is also of special interest, with the moorland plateau largely being covered by blanket bog vegetation.

Three particularly interesting localities exist within the site, which include the watershed mires at the headwaters of the Rivers Elan and Claerwen and the well developed pool and hummock mire at Gors

Lywd. Gors Llwyd is a SSSI, a Nature Conservation Review Site*Note and a Geological Conservation Review site.

The bog is also an important palynological site recording detailed evidence for vegetation and environmental change in Central Wales during the Devensian late-glacial and Holocene. The bog represents an essential site for studies of regional variations in vegetation history in Wales. The upper Elan is also a particularly good example of an upland meandering stream in a low relief floodplain, showing several contrasting planform types.

Inundation could also result in the loss of an important hay meadow SSSI, Cae Aberglanhirin, and other locally important hay meadows. Cae Aberglanhirin SSSI is a good example of a type of upland, species rich hay meadow that is now rare and restricted to a few localities in mid-Wales. It lies adjacent to the headwaters of the River Elan.

Numerous other sites may be affected by construction and road diversion including Caeau Troed - rhiw - drain SSSI, Coed yr Alltgoch SSSI and Rhos-yr-hafod SSSI.

Elenydd is one of the two most important areas in Wales for upland bird species, forming the feeding range for a larger part of the British population of Red Kite. The Red Kite is a rare breeding resident in Britain, once widespread, its persecution lead to near-extinction in late 19th century. In 1987 there were 52 nesting pairs in Wales. The species is still limited to a restricted area of Wales. The whole area is currently being proposed as a Special Protection Area (SPA) under the European Community Directive (79/409) on the Conservation of Wild Birds. The Directive requires members states to take special measures to conserve the habitats of certain rare, vulnerable or migratory species.

Mitigation

With respect of agricultural mitigation measures, the ground cover of remaining land could be improved and shelter provided by planting trees as windbreaks, or the present number of holdings could be reduced to provide a smaller number of viable units. However this is likely to have adverse effects on nature conservation. Relocation of boundaries for the remaining tenants is also difficult for flocks of sheep inherit an attachment to a particular area known as a sheep walk. This attachment is passed onto following generations. Compensation or alternative farmsteads could be provided for loss of property. Significant improvements could arise from better access to remaining farms. It would be difficult to mitigate impacts on sites of nature conservation interest.

*Note: The physical features are of national importance and have been selected as a result of the former Nature Conservancy Council's Geological Conservation Review, a national survey and evaluation of sites of ecological and physiographical interest. Part of the site is listed in A Nature Conservation Review, Ratcliffe (1977).

Benefit Opportunities/Recreation-Amenity

The large area of water formed by the proposed reservoir could provide excellent opportunities for water based recreation, although the remoteness and climate are more likely to attract sightseeing, walking and photography than fishing and yachting.

Summary

Enlargement of Craig Goch does not appear to result in significant community or archaeological impacts, however, there are serious nature conservation issues arising from the scheme. Whilst the existing reservoir can be valuable in winter months when small numbers of tufted duck, goldeneye, goosander and the occasional whooper swans may occur, on the whole the deepsided reservoir has limited wildlife potential. The Countryside Council for Wales would strongly object to any proposals which affect Elenydd SSSI and associated habitats of value, due to its national and possibly international importance. The reservoir could provide significant recreation and amenity benefits.

5.2.2 Tunnel Aqueduct to River Severn (Llanidloes)

There is no specific information on the general planning constraints between Craig Goch and Llanidloes. There are a number of sites of nature conservation value in the area including the Wye SSSI, and careful planning and construction would be required to avoid adverse impacts.

5.2.3 River Severn, Llanidloes to Coalport

General Character

The upper Severn downstream of Llanidloes is a semi-natural middle order broad river with moderate slope and a boulder clay/alluvial gravel bed. The depth regime is responsive to changes in flow, although there are a number of depth regulating weirs, notably for the intake to the Montgomery Canal at Newton. The river is regulated by releases from Clywedog reservoir at low flows.

Hydrology

The catchment area at Llanidloes is about 180 km^2, but the nearest gauging station downstream on the Severn at Abermule, approximately halfway between Llanidloes and Shrewsbury, has a catchment area of 580 km^2. The mean annual flow at Abermule is 1204 Ml/d and the Q_{95} low flow is 149 Ml/d. The low flow release from Clywedog reservoir is up to 500 Ml/d between March & October and up to 2000 Ml/d at other times, and up to 405 Ml/d from Vyrnwy, both linked to the gauged flow at Bewdley. The minimum recorded mean daily flow at Abermule was 35 Ml/d in September 1976 and the MAF is greater than 20000 Ml/d.

The effect of regulating the Severn with up to 600 Ml/d of water from Craig Goch would be to increase the magnitude of low flows by a factor of up to 5. Whilst the channel could undoubtedly accommodate these flows, the low flow regime would be altered significantly. The median flow would be maintained for most of the year. There would be negligible change to the high flow regime. The effect of regulation would be to make the upper Severn one of the most regulated rivers in Britain (compared to the natural low flow regime), with a marked reduction in the variability of flows, especially low flows. With a frequency of operation of once every two years, the period of lowest flows would become the late spring period just before the transfer regulation started to operate. The study by Hey (1980) suggested that a flow less than 900 Ml/d was unlikely to cause channel stability problems.

The magnitude of the changes to the flow regime decreases downstream such that by Buildwas gauging station, just upstream of Coalport, the regulation flow of 600 Ml/d would increase the Q_{95} flow by about 60%.

Water Resources

There are no apparent detrimental impacts on water resources on this reach.

Water Quality

There has been no recent work undertaken to investigate the impact of Craig Goch releases on the Severn, however this was studied by Balfour (1974). In this study at the Q_{80} flow of 65 Ml/d in the Severn and an 875 Ml/d release from Craig Goch the pH was predicted to fall from about 6.5 to 6.0 with a corresponding drop in hardness from 21 mg/l to 12.8 mg/l and alkalinity from 11.5 mg/l to 6.75 mg/l. The colour was predicted to increase from 6.1°H to 11.9°H. However, all these changes are within the natural range of variation.

Release of cold, deoxygenated water taken from depth in the reservoir would affect water quality and biota, and care should be taken in draw-off arrangements to match releases to ambient river conditions.

Fisheries

From the confluence of the Severn with the Dulas just upstream of Llanidloes the Severn is a good trout and salmon nursery and trout river. Some of the upper tributaries are affected by acidification, but the quality is good from Llanidloes downstream. About 10km downstream at Llandinam, grayling, dace and a few chub are present. By Newtown the river is a mixed fishery of coarse fish and trout, but with salmon as well.

Surveys of fisheries have been carried out regularly and there is good data for the upper reaches. However the main river from Llanidloes to

Newtown is 40-50m wide, but with very low conductivity which reduces the effectiveness of the electrofishing.

The upper Severn is an EC designated salmon fishery above Shrewsbury weir. Average salmon redd counts between 1975-91 were 102 for the stretch between Felindre-Dolwen, 56 for Dolwen-Llandinam, 77 for the stretch between Llandinam and Caersws, 81 between Caersws and Newtown and 58 between Newtown and Welshpool. The tributaries are very important as recruitment areas for salmon.

The scheme is expected to have negligible effects on the high flow regime in the upper Severn, but low flows would be increased by a factor of five with the effect that median flows would be maintained for most of the year during regulation, every other year on average.

These changes would be expected to have a significant effect on the extent of inundation of salmonid nursery areas in late summer, with less of an effect on migration and spawning. Detailed studies of channel configuration and gradients would be required in order to assess the extent to which increased summer flows which result either in increased nursery area or entrained velocities unfavourable for juvenile fish. Overall, the impact is viewed as locally high, but with possible benefits in terms of reduced flow variability.

Discharge of cold, deoxygenated water would affect the fishery and care would be needed in the draw-off arrangements for regulation, such that the discharged water matches river temperatures and dissolved oxygen content as closely as possible.

Aquatic Ecology

Macroinvertebrate sampling is undertaken at a number of sites along the Severn between Llanidloes and Coalport. The biological quality at all of these sites could be classified as good to excellent and fall into biological band A.

At Llanidloes (SN94908410) the BMWP score is 145, with 21 taxa and an ASPT of 6.9. Further downstream at Aberbechan (SO14309350) the BMWP score is 158, with 24 taxa and an ASPT of 6.6. At Montford bridge (SJ43201530) the BMWP score of 183, 29 taxa and an ASPT of 6.3. Finally at the last sampling point upstream of Coalport, Cressage (SJ59400460) the BMWP score is 177, with 32 taxa and an ASPT of 5.5.

Impacts on aquatic ecology through this already regulated section are unlikely to be significant. Care should be taken to ensure that some marginal seasonal-dry, gravel-cobble habitats are exposed; mitigation measures may be required.

Terrestrial Ecology

There is no data on the extent of riparian sites of ecological interest between Llanidloes and Coalport. However, the proposals are unlikely to affect such sites.

Summary

While this stretch of river is already regulated, there would be a significant increase in low flows in the upper Severn, with the release being 5 x Q_{95} at Llanidloes and 0.6 x Q_{95} near Coalport. Water quality may alter as a result. Care should be taken to match the releases to ambient river temperature and dissolved oxygen content using multiple draw-off arrangements. This will possibly minimise effects on water quality and biota. Significant changes will occur in the inundation of salmonid nursery areas, and to a lesser extent to migration and spawning of salmonids. The potential impact is locally high and further work is required on this good trout and salmon nursery, and trout river.

5.2.4 River Severn, Coalport to Deerhurst

General Character

The Severn downstream of Coalport is a semi-natural regulated river with a lowland character. The low flow regime is strongly influenced by releases from Clywedog and Vyrnwy reservoirs and augmentation from the Shropshire groundwater scheme.

Hydrology

Downstream of Coalport, the low flow regime would increase such that the Q_{95} flow would increase by about 40%. The seasonality and variability of flows in the middle reaches of the Severn would remain essentially unaltered.

Water Resources

There are no apparent impacts on water resources in this reach.

Water Quality

Balfour (1974) predicted the impact of Craig Goch water on the Severn at Shelton would result in the river being dominated by water from Craig Goch. At Trimpley, upstream of Kidderminster, there are predicted reductions in hardness, alkalinity and chloride although still within the natural range of variation. By the time the river reaches Upton gauging station with a Q_{95} of 2179 Ml/d the impacts of Craig Goch water will be greatly reduced. There may be reductions in colour, nitrate and ammonia. This will also be the case downstream at Haw Bridge with additional decreases in hardness, alkalinity and chloride levels.

Fisheries

The Severn is an EC designated cyprinid fishery from the Avon confluence upstream to Shrewsbury weir, and a salmon fishery thereafter. Upper Severn fisheries are described in Section 5.2.3. In the lower Severn there are problems with fisheries survey because of the size of the river (see Severn-Thames transfer - Option 1). No significant impacts are foreseen.

Aquatic ecology

As described in Section 5.2.3 the biological quality in the upper and middle Severn can be classified as good to excellent. The river continues to have a diverse range of taxa to Bewdley (SO78707540) with a BMWP score of 215, 37 taxa and an ASPT of 5.8. All sampling locations fall into biological band A. However downstream of Bewdley few data are available and sampling becomes increasingly difficult. It is known that biological quality significantly deteriorates below Tewksbury due to the heavy clay substrate. (See Severn-Thames transfer - Option 1). There are unlikely to be any adverse effects on aquatic ecology.

Summary

This section of river is already regulated. The additional regulation will increase flows by 0.4 x Q_{95} at the upper end and minor water quality changes may occur. No significant changes in biota or fisheries are anticipated, although more detailed studies should be undertaken.

5.2.5 Severn-Thames Transfer

The general impacts of this component are described in Section 5.1. The key difference between the unsupported Severn transfer and the transfer with the Severn regulated by Craig Goch are:

- There would be little impact on the reach downstream of Deerhurst, since the abstracted quantity would be balanced by the reservoir releases (this would have to be carefully monitored to allow for travel times and other variable upstream releases and abstractions).

- With no flow constraint in the Severn restricting periods of abstraction, both the frequency and the duration of transfers would increase compared to Option 1. The resource value would increase to 425 Ml/d and the transfer would be used about once every two years (33 out of 72 years - NRA Thames Region 1993) for an average of 121 days/year.

- Hydrological impacts in the Thames & Severn Canal and in the Thames at Buscot would be comparable in magnitude to the unsupported transfer (Option 1), but would be more severe in frequency and duration, particularly over the summer low flow months.

- The water quality of the Severn at Deerhurst with Craig Goch regulation would be significantly different from the existing conditions, and therefore the water quality implications of the transfer are adequately covered by Option 1.

5.3 OPTION 3: Craig Goch Regulation of Wye

Description

This option was examined in the 'Other Options' report by Halcrow (1993). There is no separate 'Option Study' report and assessment has had to be based partly on the Halcrows report and partly on the study reports prepared for the Water Resources Board between 1972 and 1980. The option considered here is the smallest reservoir size, fed only by natural runoff from its own catchment. The engineering works involved are:

- New earthfill dam, downstream of existing dam, to a height of 86m and a top water level (TWL) = 366m AOD;
- Temporary and permanent road diversions;
- Tunnel aqueduct from Craig Goch to Nannerth;
- Pipeline from Ross-on-Wye to Deerhurst and then Deerhurst to Thames as for Option 1.

Assumptions:

- Scheme operated on a put and take basis, i.e., regulation matches abstraction;
- Maximum regulation of River Wye 400 Ml/d;
- Maximum Wye-Thames transfer capacity 400 Ml/d;
- No Abingdon Reservoir.

The summary environmental assessment for this option is shown in Table 5.3, while assessments for each component are presented in Appendix D.

5.3.1 Enlarged Craig Goch

This component is the same as that presented in Section 5.2.1 above with the same top water level of 366m AOD, however, the maximum regulation release in this case is 400 Ml/d regulating the River Wye, whereas under the option presented in 5.2.1 the maximum regulation release is 600 Ml/d regulating the River Severn.

TABLE 5.3 Option 3 Environmental Assessment

OPTION 3. Craig Goch Enlargement & Wye Regulation
REGULATION: 400 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
3.1	Enlarged Craig Goch																		
3.2	Pipeline: Ross–on–Wye to Deerhurst																		
3.3	Pipeline: Deerhurst to Down Ampney																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
3.4	R.Wye Nannerth to Ross–on–Wye																		
3.5	Pipeline: Ross–on–Wye to Deerhurst																		
3.6	Pipeline: Deerhurst to Down Ampney																		
3.7	Gravel Pits at Down Ampney																		
3.8	Thames & Severn Canal																		
3.9	R.Thames at Buscot																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

5.3.2 Tunnel to Nannerth

The entire length of the river Wye has been designated a SSSI and the proposed outfall structures and tunnel construction would need careful planning and design. Care would need to be exercised throughout the construction phase to minimise impact on the environment.

5.3.3 River Wye, Nannerth to Ross-on-Wye

General Character

The Wye downstream of Nannerth is a natural, steep, unregulated, upland river with a rock and gravel bed. The proposed discharge point is at Nannerth on the upper Wye, upstream of any existing regulation from the Elan Valley Reservoirs. The confluence of the Wye, and the Elan River is about 6 km downstream of Nannerth.

Hydrology

The gauging station just downstream at Ddol Farm (catchment area 174 km^2) has a mean flow of 556 Ml/d, Q_{95} of 46 Ml/d, and MAF of greater than 10000 Ml/d. The next gauging station on the Wye downstream of the Elan confluence is at Erwood (catchment area 1282 km^2), with mean flow of 3100 Ml/d, Q_{95} of 382 Ml/d and MAF of greater than 45000 Ml/d. By the nearest gauging station to Ross-on-Wye at Belmont catchment area 1896 km^2, the Q_{95} flow has increased to about 520 Ml/d.

The peak regulation release of 400 Ml/d into the Wye at Nannerth would have a dramatic (10 x Q_{95}) impact on the previously natural flow regime of the 6km reach from the discharge point to the confluence with the River Elan. Downstream of the confluence, the effects would be less because of the existing releases from the Elan Valley Reservoirs but the Q_{95} at Erwood would be slightly more than doubled. By the proposed abstraction point at Ross-on-Wye, the Craig Goch releases would double the existing Q_{95} flow, making dry summer flows appear like wet summer flows. There would be a longer duration of above average flows in years in which the release operated. In the upper reaches there would be a change in seasonality of average flows, but this effect would be negligible in the lower reaches where the river is already heavily regulated.

Water Quality

The River Wye at Nannerth Bridge, where water would be discharged from Craig Goch, is classified as NWC Class 1A. No data for the River Wye were available in previous study reports therefore data was obtained directly from NRA Welsh Region. The pH of the river water ranges between 6.4 and 7.6 with a mean of 6.8 and a 95 percentile of 7.35. Balfour (1974) predicted that an enlarged Craig Goch would have a pH of 5.7 to 5.9. Total suspended solids ranges from a minimum of 3.0 mg/l to 8.0 mg/l with a mean of 3.6 mg/l and 95 percentile of 5.45

mg/l. The water temperature ranges from 1°C to 16.5°C with a mean of 8°C. The BOD level ranges from 0.5 mg/l to 2.5 mg/l with a mean of 1.1 mg/l and 95 percentile of 2.3 mg/l. Ammonia levels vary from 0.010 mg/l to 0.090 mg/l with a mean of 0.015 mg/l & 95 percentile of 0.029 mg/l. The DO expressed as % saturation ranges from 82.6 to 104.0 with a mean of 94.6 and 95 percentile of 103.7.

The River Wye drops to NWC Class 1B at Bridge Sollars bridge, upstream of Hereford, and remains NWC Class 1B at Wilton Bridge in Ross-on-Wye.

At Ross-on-Wye the pH of the river water ranges between 7.4 and 9.0 with a mean of 7.9 and 95 percentile of 8.5. Conductivity ranges from 144 mS/cm to 360 mS/cm with a mean of 235 mS/cm and 95 percentile of 343 mS/cm. Total suspended solids ranges from a minimum of 3.0 mg/l to 42.0 mg/l with a mean of 11.8 mg/l and 95 percentile of 30.8 mg/l. The water temperature ranges from 3°C to 20°C with a mean of 11°C and 95 percentile of 24°C. The BOD level ranges from 0.8 mg/l to 6.1 mg/l with a mean of 1.9 mg/l and 95 percentile of 3.7 mg/l. Ammonia levels are slightly higher than at Nannerth with a mean of 0.028 mg/l and 95 percentile of 0.071 mg/l. The DO expressed as % saturated is 96 on average with a 95 percentile of 120. The TON ranges from 1.19 mg/l to 5.85 mg/l with a mean of 3.02 mg/l and 95 percentile of 5.06 mg/l. The orthophosphate levels range between 0.026 mg/l & 0.910 mg/l with a mean of 0.115 mg/l and 95 percentile of 0.236 mg/l. Chloride levels are on average 17.8 mg/l with a 95 percentile of 23.9 mg/l.

Craig Goch, which lies in the upper reaches of the Wye catchment, is not at present used to make compensation releases into the River Wye. Releases of water from the reservoir might have an impact on the water quality of the River Wye downstream, but this could be minimised by ensuring that the take-off points do not produce water of different temperature and oxygen content to the river. Further studies are needed in this respect.

Fisheries

In general, the Wye is considered the best salmon river south of the Scottish border. The upper Wye is a key spawning area for salmon and trout and all the major tributaries are significant spawning areas. The long term average is >3000 rod caught salmon a year although recent returns have been about 2000 a year. An NRA (1992) report on the Regional Juvenile Salmonoid Monitoring Programme noted that the highest densities of salmon fry was found in the Garth Wales, Ediw and Duhonw and the highest densities of parr on the Clywedog, Duhonw, South Dulas and Commarch. Mean trout densities were reported as increased since 1991, and mean salmon densities slightly lower than 1991.

The discharge from Craig Goch would be released below the area of worst acidification in the upper catchment. This area has resident trout and juvenile salmon, and brook lamprey. Adult salmon are present at times, mainly in the spawning season. Downstream there are stone loach and minnow. At Rhayader, there are some chub in small shoals, but they are limited. At Builth Wells, there is a good coarse fishery comprising chub, dace, pike, eel and at Ross on Wye, there are 24 species of fish. Shad move upstream as far as Builth Wells to spawn and sea lamprey migrate upstream to Earlwood in June/July.

The Wye is a very popular coarse fishing river. The main river is not heavily fished for trout, although there is fishing on the tributaries.

However, principal concerns for fisheries centre on the salmonid spawning reaches of the upper Wye and the extent to which these may be affected by the altered low flow regime, and by possible changes in water quality, particularly temperature and dissolved oxygen. To some extent, enlargement of Craig Goch within the catchment might serve to reduce peak flows during spate.

The area of greatest impact will stretch for approximately 6km from the discharge point down to the Elan confluence, where mean flow would be doubled. Depending on channel configuration, areas might be subject to increased velocities and depth, with risk to spawning and nursery areas. From the Elan confluence to Ross-on-Wye there would be a doubling of Q_{95} flow and possibly some reduction in the peak velocities under spate and there might be significant effects at spawning times. Mean flows would be increased marginally by 13% but essential characteristics of the river channel in terms of width, depth and velocity should be retained.

In terms of reduced 'naturalness', the impacts on fisheries are viewed as high. Confusion may occur with homing salmonids as a result of changes in "smell" of the river. At the same time however, moderation of extreme low and high flows might provide benefits in terms of reduced environmental risk and improved habitat stability.

Careful planning design and operation of draw-off arrangements would allow discharges to be matched as closely as possible with river temperature and oxygen content, thereby minimising potential impact on fisheries and on aquatic ecology.

As the volumes of augmentation and abstraction will be equivalent, there will be little downstream effect on fisheries below Ross-on-Wye. Care should be exercised in design and location of the intake in order to minimise risks of fish entrapment.

Aquatic Ecology

The Wye is of national importance as an example of a major river which has a largely natural regime. The Wye supports a variety of aquatic animal and plant communities reflecting the various types of river bed, flow and water chemistry. The upper reaches are comparatively poor in numbers of species with stoneflies and mayflies predominating. The middle reaches are characterised by an increase in aquatic plants and animals, notably caddis flies and crayfish. In the lower reaches snails, shrimps and slaters become more common among the large water crowfoot beds. The river is noted for invertebrates of restricted distribution in Britain and an assemblage of so many uncommon species in one river is unusual.

The macroinvertebrate fauna from source to mouth of the Wye falls into biological class A with many BMWP scores being over 200. Sampling sites at Builth Wells (SO04225155), Hafodygarreg (SO11264164), Glasbury (SO18003925) and Whitney (SO2624720) all located in the upper Wye have scores as follows: Built Wells (BMWP 183, ASPT 6.8); Hafodygarreg (BMWP 188, ASPT 6.5); Glasbury (BMWP 194, ASPT 6.5) and Whitney (BMWP 201, ASPT 6.7).

The abstraction point at Ross on Wye has a BMWP score of 183 and an ASPT of 6.10.

The maximum regulation release of 400 Ml/d would cause a ten-fold increase in low flows at the release point but this would decline to about a two-fold increase 30km downstream of the Elan - Wye confluence. Impacts on high flows are particularly important for channel morphology and channel bed stability/sedimentation which have not been assessed. From experience elsewhere, floods are unlikely to be significantly affected at Erwood.

Major impacts on aquatic ecology are likely to be confined to the short (ca 15 km) reach from the discharge downstream to the Ithon confluence. Although the river is already regulated to a minor degree by the Elan reservoirs, the river has high naturalness and as stated is a SSSI; as such the magnitude of impact is considered to be high because the natural condition of this high-order river, which is rare in the UK, should be protected.

Terrestrial Ecology

No detailed information is available on the extent of specific sites of nature conservation interest along the Wye. However, the whole river including the riparian habitats has been classified as a SSSI and as such is of national value. Regulation is unlikely to adversely affect sites of riparian interest, as channel alteration is not necessary to accommodate increased flows, however, this would need further consideration. Any infrastructure should be carefully sited and consultation should take place with The Countryside Council for Wales and English Nature. Possible effects on protected species such as the otter which occur along the Wye would need further consideration.

Recreation/Navigation/Amenity

The Wye is an important recreation and amenity centre. Primary concern must be for the effects of the regulation on coarse and migrating salmonid fishing, on what is the best salmon river in England and Wales. There might also be implications for canoeing, due to the increased velocities.

Summary

The Wye is a unique aquatic environment in Britain, a SSSI of international importance, and the best salmon river in England and Wales. The proposed regulation would increase low flows by 10 x Q_{95} in the reach above the Elan confluence, and 2 x Q_{95} at Ross-on-Wye. Seasonality would change in the upper reaches. Water quality changes and effects on biota/fisheries would depend in part on the extent to which draw-off arrangements could allow releases to be matched with ambient river temperature and dissolved oxygen concentration. There would be very significant impacts on aquatic ecology and salmonid fisheries from these flow, velocity and water quality changes. Principal areas of concern are the salmonid spawning reaches in the upper Wye, and to a lesser extent nursery areas and migration of salmonids. It is recommended that this option should not be pursued in the light of these environmental risks.

5.3.4 Pipeline, Ross to Deerhurst

No information was obtained on the land use planning constraints between Ross and Deerhurst since route corridors have not been investigated in previous studies.

5.3.5 Deerhurst-Thames Transfer

The general impacts of this component are described in Section 5.1. The key difference between the unsupported Severn transfer and the transfer of water from the Wye are:

- With no flow constraint in the Severn restricting periods of abstraction, both the frequency and the duration of transfers would increase compared to Option 1. The resource value would increase to 425 Ml/d and the transfer would be used about once every two years (33 out of 72 years - Ref. NRA Thames Region 1993) for an average of 121 days/year.

- Hydrological impacts in the Thames & Severn Canal and in the Thames at Buscot would be comparable in magnitude to the unsupported transfer (Option 1), but would be more severe in frequency and duration, particularly over the summer low flow months.

- The water quality of the Wye regulated by Craig Goch would be significantly different from transferring water from the lower Severn. No water quality studies have been undertaken to investigate the differences between the present water quality of the Wye at Ross and the Thames at Buscot. The catchment of the Wye to the proposed abstraction point at Ross-on-Wye is about half the size of the Severn catchment and is less affected by industrial and urban effluents. Although the impact of transferring Wye water is likely to be less severe than transferring Severn water, in the absence of detailed water quality studies, it has been assumed that there is a high risk of adverse impact to the chemistry of the upper Thames.

- Based on information obtained from the RIVPACs classification of the Wye at Ross-on-Wye, and the Thames at Buscot, there is a low degree of similarity between the invertebrate fauna of both river. This contrasts with the high level of similarity between the invertebrate fauna of the lower River Severn and the Thames at Buscot.

- Expected effects on fisheries in the Thames at Buscot are similar to those described for the Severn Thames transfer (Option 1), except that water quality from the Wye at Ross-on-Wye is likely to be less variable than the Severn.

5.4 OPTION 4: Vyrnwy Redeployment for Severn Regulation

Description

Halcrow (1992) examined this option in terms of engineering feasibility and cost. Resource modelling and hydrological studies were undertaken by NRA Severn-Trent Region (1993). The engineering works involved are:

- Possible new draw-off facilities with tunnel to discharge to River Vyrnwy.
- Severn-Thames transfer components as per Option 1; maximum Severn-Thames transfer capacity 300 Ml/d.

Assumptions:

- Maximum additional release for Severn regulation of 300 Ml/d.
- Prescribed flow in River Severn at Bewdley of 850 Ml/d.
- Prescribed flow in River Severn at Haw Bridge of 2500 Ml/d.
- No Abingdon Reservoir.

The summary environmental assessment for this option is shown in Table 5.4, and detailed assessments of the components are given in Appendix D.

5.4.1 Vyrnwy Reservoir

There would be no change to the existing Vyrnwy Reservoir other than possibly in the draw-off arrangements.

Halcrow proposed three draw-off options:

- The existing draw-off facilities for all necessary regulation releases; these are at present used for compensation releases. In this option Vyrnwy would be the baseload regulator and Clywedog would be operated to fine tune the total regulation need.

  Water would be drawn from the cold, less oxygenated deep water which could lead to detrimental environmental impact.

- Reduce potential discharges to the River Vyrnwy by constructing a pipeline works from the Hirnant or Aber draw-off routes to a new outfall on the River Tanat. Use of the Hirnant draw-off facilities would allow water to be abstracted from different reservoir levels to match river temperatures and quality more closely.

- Construct new draw-off facilities comprising new draw-off tower connected to a new tunnel bored through one of the side abutments and around the dam to discharge into the River Vyrnwy. This would have the water quality advantages of the last option, and would improve the operational capability of the reservoir.

The main drawback with the tunnel to the River Vyrnwy option is the need to draw down the reservoir to carry out the works, although the opportunity can be used to carry out maintenance works. Together with refill time the reservoir could be out of operation for several years.

5.4.2 River Vyrnwy to Severn Confluence

General Character

Vyrnwy Reservoir already regulates the river Vyrnwy, receiving normal compensation releases of 45 Ml/d and maximum releases of 450 Ml/d. For many years up to 1978 monthly freshet releases were made for a period of up to four days each month, resulting in an increase from 45 to 225Ml/d for the months March to October. The impact of these existing regulation releases has never been assessed in detail.

TABLE 5.4 Option 4 Environmental Assessment

OPTION 4. Vyrnwy redeployment & Severn – Thames Transfer
REGULATION: 300 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
4.1	Pipeline: Deerhurst to Down Ampney	High	Moderate	Moderate	High	High	Moderate	Low	Low	Low	Low	Low	Low						

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
4.2	Vyrnwy Redeployment	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low						
4.3	R.Vyrnwy to R.Severn	Low	Low	Low	Low	Low	Low	Low	High	Moderate	Low	Low	Low	Moderate	Moderate	Low	Low	Low	Low
4.4	R.Severn to Deerhurst	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	High	Moderate	Low	Low	Low	Moderate	Moderate				
4.5	Pipeline: Deerhurst to Down Ampney	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low						
4.6	Gravel Pits at Down Ampney																		
4.7	Thames & Severn Canal	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low		Moderate	Moderate	Moderate	High	Low
4.8	R.Thames at Buscot	Low	Low	Low	Low	Low	Low	High	High	Low	Low	Low	Low		Low	Low		Moderate	Low

RISK/OPPORTUNITY KEY:

- HIGH (black)
- MODERATE (dark grey)
- LOW (light grey)
- NOT APPLICABLE (white)

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

Assessment of the impact of additional regulation is therefore rather constrained.

In character the river is a typical flashy rock and gravel bed river. Downstream of release sites the fauna have been observed by the NRA to be sparse, although the particular reason for this is not known. In the past uncontrolled releases have caused scour. The reach affected by increased regulation is 16 km long.

Hydrology

At Llanymynech gauging station near the confluence with the River Tanat, the mean annual flow is 1813 Ml/d (catchment area 778 km^2). The Q_{95} low flow is 181 Ml/d, and the minimum monthly flow was 87 Ml/d in August 1976.

The River Tanat has a mean flow of 552 Ml/d at Llanyblodwel gauging station, just near the Vyrnwy confluence (catchment area 229 km^2). The Q_{95} low flow is 43 Ml/d and the minimum monthly flow was 16 Ml/d in August 1976. Flows at the proposed discharge point will be about one third of these values, that is, mean flow 184 Ml/d, and Q_{95} 5 Ml/d.

The proposed releases would be about 6 times greater than the present normal 45 Ml/d compensation releases, and would therefore dominate the low flow hydrology of the River Vyrnwy immediately below the release point.

Water Quality

The river is already regulated by releases from Vyrnwy reservoir and no significant changes in water quality are expected, although there could be impacts from low temperature and dissolved oxygen of the release water unless draw-off arrangements allow matching to ambient river conditions.

Fisheries

As with the Craig Goch regulations of the Wye and the Severn, the main fisheries concerns for the Vrynwy redeployment would centre on the relative value of the Vrynwy as a salmonid nursery stream. At present, the flow regime is characteristically flashy with a wide flow range. The proposed regime would serve to increase low flows, whilst leaving the upper flow regime essentially unaltered. Migration and spawning are, therefore, likely to be of less concern than the maintenance of stable nursery areas without excessive washout. Consideration should therefore be given to the development of stream stability through suitable operating regimes.

Particular concerns relate to an increase in scour, changes in sedimentation, quality of released water, and temperature of the released water. These factors could be mitigated to an extent by the measures described in Section 5.4.1, namely by limiting releases to the River Vyrnwy and discharging instead to the River Tanat, and by selective draw-off from different reservoir levels to minimise differences in temperature and water quality from ambient river conditions.

Aquatic Ecology

This option would increase the flow in the Vyrnwy by discharging a maximum of 300 Ml/d of hypolimnial water, and would be likely to have a major impact on the low-flow regime and hence aquatic ecology for more than 30 km.

Variation of the proposal by use of multiple draw-offs to mitigate temperature and water-quality problems is likely to be successful and impacts on aquatic ecology would be reduced. Discharging some of the water to the Tanat via the Hirnant would protect the Vyrnwy but would have major impacts on the Hirnant and Tanat which are not regulated at the present time.

Summary

The river Vyrnwy is already subject to compensation releases of between 45 and 450 Ml/d, which have given rise to scour and wash-out. However, the proposed releases would be 6 x the present normal releases and over 2 x Q_{95}, and would dominate the hydrology of the river. Impacts would be significant and particular concerns are increases in scour, changes in sedimentation, quality of released water and temperature of released water. These changes would seriously affect the salmonid nursery, and to a lesser extent salmonid migration and spawning, and aquatic ecology . Some mitigation could be achieved by limiting releases to the Vyrnwy and discharging water to the Tanat, by suitable operating regimes to limit changes in flow, and selective draw-off from different reservoir levels.

5.4.3 River Severn, Vyrnwy Confluence to Deerhurst

The upper Severn is also presently augmented by releases from Clywedog (500 Ml/d max), and by the Shropshire Groundwater Scheme in drier years (85 Ml/d max). Together with the Vyrnwy compensation flows, releases are made to maintain flows at the Bewdley control point above a prescribed flow of 850 Ml/d in order to meet licensed abstraction and 'in-situ' requirements.

Some of the variations in control rules explored by NRA Severn-Trent Region require additional releases from these other sources as well as Vyrnwy, while others link Vyrnwy and Clywedog releases and require little change in the groundwater scheme contribution.

At Bewdley, increased flows of 300 Ml/d are significant compared to the prescribed flow of 850 Ml/d and a Q_{95} of 947 Ml/d, and the flow regime of the river will be altered. The release would be 50% of the lowest mean monthly flow of 645 Ml/d in August 1976.

Vyrnwy reservoir already regulates the Severn and no significant changes in water chemistry are expected as a result of increased regulation.

Issues relating to water resources, fisheries and aquatic ecology were discussed for this reach in Sections 5.2.3 and 5.2.4 for the Craig Goch regulation option of up to 600 Ml/d. Impacts from the Vyrnwy regulation option of 300 Ml/d maximum release would be reduced accordingly. Further studies and investigations are required, particularly at the upstream end of the reach.

5.4.4 Severn-Thames Transfer

This part of the Vyrnwy redeployment option has already been described in Section 5.1. Differences relate to the maximum possible transfer based on Vyrnwy releases of 300 Ml/d, whereas a minimum of 400 Ml/d is considered in Section 5.1, and to the negligible effect on the Severn downstream of Deerhurst, since abstraction would be matched to the releases.

5.4.5 River Thames, Buscot to Egham Reach

Effects of the transfers would be much as those set out in Section 5.1, apart from the fact that the timing would no longer be constrained by 'natural flows' in the Severn, maximum transfer would be 300 Ml/d rather than 400 Ml/d, and water quality should be marginally improved. The scale of the impacts would be proportionately decreased.

5.4.6 Knock-on Resource Development in North West Region

Redeployment would involve changes in operation of Lake Vyrnwy, including development of additional water resources within the North West to meet demands presently met from this source. The implications of the latter have not been taken further in the present study but would need to be examined if this option is to be pursued.

5.5 OPTION 5: South West Oxfordshire Reservoir Regulating Thames

Description

Although several detailed environmental studies have been carried out by Thames Water PLC, none of the reports were available for the present study. This assessment is, therefore, based on the reports by WS Atkins (1993) and Howard Humphreys (1992), combined with the public information leaflet "Reservoir News" released by Thames Water in February 1993. The engineering components are assumed to comprise:

- An embanked, irregular, landscaped reservoir (clay, with gravel drains), approximately 25m high near Abingdon;
- Intake and discharge works in the River Thames at Culham;
- Pumping station;
- Pipeline from the reservoir to Culham.

This is outline design information only. The original reservoir was proposed at 150000 Ml storage. Latest information and NRA simulations are based on 100000 Ml storage, which would lead to a lower embankment height, say 20m, with correspondingly lower visual impacts.

Assumptions

- The maximum discharge from the reservoir at low flows would be about 400 Ml/d (NRA Thames Region 1993);
- No transfers from outside Thames Region.

The summary environmental assessment for this option is shown in Table 5.5, and detailed assessments of the components are presented in Appendix D.

5.5.1 South West Oxfordshire Reservoir

Land Use

Land take would be extensive, however, the Agricultural Land Classification is Grade 3 and 4, and therefore, impacts have been considered moderate to low.

Landscape/Visual

The site is not subject to national or local landscape designations, and therefore, landscape impacts are unlikely to be significant. However, due to the presence of a structure such as this, in a low lying area, the existing relationship between the lowland area and higher ground, the Downs, might be affected.

Due to the close proximity of Steventon and Drayton, and the fact that the site is overlooked by higher ground (the ridgeway), the visual impacts would be major.

Archaeology

There are no Scheduled Ancient Monuments in the area, although a number of archaeological sites/artifacts of interest would be inundated. Impacts are likely to be moderate or low. Field surveys are currently being undertaken for Thames Water.

TABLE 5.5 Option 5 Environmental Assessment

OPTION 5. South West Oxfordshire Reservoir & Thames Regulation
REGULATION: 400 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
5.1	South West Oxfordshire Reservoir																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
5.2	R.Thames d/s Culham Reach																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

Terrestrial Ecology

The proposed area is under intensive agricultural production and therefore of limited nature conservation value. There are no designated conservation sites directly affected, with wildlife interest concentrated in small areas of more semi-natural habitat. Possible impacts to the Barrows Farm Fen SSSI located 2-3km upstream on the Sandford Brook would need to be considered.

General Planning

The impacts arising from the construction of the scheme would be considerable. Although not involving the loss of a significant number of properties, the site would be in close proximity to Steventon and Drayton with consequential potential for disturbance from noise, dust, vibration and traffic movements.

Mitigation

With appropriate landscape measures to the reservoir itself and any associated infrastructure, it would be possible to partially mitigate some of the most detrimental impacts. There would be an inevitable effect on the local landscape although this would not necessarily be adverse.

Opportunities for Enhancement

With careful design and management the reservoir could provide a significant recreational resource, with the creation of sailing, canoeing, and other water based recreation. The reservoir could also be of benefit to wildlife. A number of existing reservoirs have been designated SSSI's usually for their wildfowl interest.

Summary

The most significant impacts relate to construction with elevated noise, traffic and dust for local residents. These would continue for a number of years and could be considered as severe. Apart from construction impacts and visual impacts which should in part at least be mitigable, the scheme appears to be acceptable from a land use planning perspective.

5.5.2 River Thames, Culham to Egham Reach

Water Quality

The general characteristics of the reach are discussed in Section 5.1.5. The nearest gauging station is downstream at Days Weir, where low flows are less than half the proposed maximum regulation releases. The overall changes likely to arise are within the existing range for both the quality and quantity regimes. Unlike the Severn-Thames transfer options, the water would be derived from the Thames and water quality should not be an issue, although operational precautions would be needed to avoid the accumulation of pollutants. Thus abstraction of high flows and regulation at low flows should have no adverse impacts on water quality in the Thames provided operating rules are set, incorporating prescribed flows, flow rate changes, and release water quality, so as to protect in-stream interests. Further work is required to establish the latter.

Fisheries

The Thames between Culham and Egham Reach is deep and slow flowing, with excellent coarse fisheries. Electrofishing surveys have been impractical due to the depth of the river, and data from recent acoustic surveys was not available at the time of writing.

Discharges from the reservoir would increase Q_{95} flows in the Thames by 10% and would retain peak flows from the immediate catchment. Peak flows in the Thames would remain unaltered and the scheme is therefore unlikely to have any significant adverse impacts on fisheries provided water quality changes within the reservoir are not marked, a suitable prescribed flow is set for the abstraction, and release rate changes are not marked.

Aquatic Ecology

Data from NRA's National Data Base (1990) indicates that at Sandford Lock Cut (SP52800210) just upstream of Abingdon, the biological banding is A. The BMWP scores was 215, with 40 taxa and an ASPT of 5.4, all of which were at or above the RIVPACS predicted score for that stretch of river. At Boveney Weir downstream of Abingdon (SU94407770) the BMWP score was 202 with 38 taxa and an ASPT of 5.3, again the actual BMWP scores number of taxa exceeded those predicted for the site, and the site is classified as band A.

This scheme is unlikely to have any major impacts upon aquatic ecology providing that a natural hydrograph rise is allowed to occur from mid September through mid November - a critical period of recovery of biota after the summer drought and for salmonid spawning runs. High-flow capping should be allowed only between mid November and June.

Terrestrial Ecology

There are numerous wetland sites located downstream of Culham although they are largely of county rather than national importance. A nationally important site however is located directly upstream of the Culham reach in a seasonally flooded backwater, Culham Brake SSSI (SU 509964). This is a small area of willow carr by the Thames containing one of the largest populations of a red Data book species summer snowflake *Leucojum aestivum.* (Red Data book species are those species that are rare or threatened in Great Britain). In addition the site supports lush carr flora. The area is directly watered from the river Thames.

According to a study carried out by BBONT Berkshire Buckinghamshire and Oxfordshire Naturalist Trust in 1984, three are at least 53 wetland, carr or open water sites in the middle and lower Thames which are periodically inundated with water from the Thames. These sites range from being areas of local and county importance to sites which have not been classified as further survey is required.

Sites which are of county importance and occur downstream of Culham include Clifton Hampden Meadows (SU556957) which are a series of unimproved meadows with some open water; South Stoke Marsh (SU594844) which includes a number of wetland habitats adjacent to the river Thames; Cholsey marsh which is a (BBONT) Nature Reserve; Shillingford Meadows (SU594923) comprising a number of wet meadows and Hayward Eyot (SU543938) which comprises tall fen vegetation and other wetland habitats subject to periodic flooding.

Further study of other sites of ecological value both designated and otherwise and consultation with English Nature and the local naturalist trusts should be undertaken. This would determine where the sites are located and what levels of flooding they are currently experiencing and what level of flooding they require to sustain their conservation interest. The type of abstraction licence could aim to take into account the need for these sites to experience low level flooding. It is thought however that the Oxfordshire flood meadows above Culham are more important in nature conservation terms than those present downstream.

There are a number of other wetland sites located on the Thames tributaries which are periodically inundated, however it is difficult at this stage to determine to what extent these would be affected, if at all.

Summary

The South West Oxfordshire Reservoir would result in major short term community impacts and landscape impacts. However, the scheme obviates the need for transfer from outside the catchment with associated possible risks to the biological integrity of the Thames. Studies and investigations are required into a prescribed flow at the abstraction point, and into discharge conditions in terms of both flow, velocity and quality in order to safeguard downstream interests.

5.6 OPTION 6: Canal Transfer, Severn-Thames

Description

This option was studied in part by W S Atkins (1993) and in detail by Binnie and Partners (1993). The engineering works associated with this transfer option are as follows:

- Intake works on the River Severn at Coalport

- Highlift pump station at Coalport.

- Pipeline from Coalport to Lower Drayton on The River Penk comprising approximately 13 km of 1m diameter pipe, 13 km of 0.9m diameter pipe and 5 km of 0.8m diameter pipe (Route 1 in Atkins report).

- Balancing storage either at the start or end of the pipeline or at the watershed for 4 days transfer flow (possible use of Belvide Reservoir).

- Discharge structures at pipeline outlet into the River Penk at Lower Drayton.

- Intake from River Sow.

- Lift pump station into Trent and Mersey Canal.

- Nominal bank raising of the Trent and Mersey Canal in places between Great Heywood Junction to Fradley Junction (about 20 km in length).

- Bank raising and widening, dredging, modifications to bridges, possible widening of Thame aqueduct, three pump stations between Fradley junction and Hawkesbury Junction on the Coventry Canal (about 50 km in length).

- Bank restoration, raising and widening, dredging, modifications to bridges, weirs and siphon weirs, two pump stations, possible by-pass for River Cherwell between Hawkesbury junction and Isis Lock on the Oxford Canal (about 123 km in length).

- Outlet into the River Thames.

Under this option a maximum of 100 Ml/d would be transferred from the Severn to the Thames.
Assumptions:

- Regulated Severn plus Severn Trent transfer (same impacts as Severn Trent transfer discussed in 5.7.1 below) except discharges into the Trent and Mersey canal instead of discharge into the River Trent.

- No Abingdon reservoir.

The summary environmental assessment for this option is shown in Table 5.6, and detaield assessments of the components are presented in Appendix D.

TABLE 5.6 Option 6 Environmental Assessment

OPTION 6. Canal transfer Severn to Thames
TRANSFER: 100 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
6.1	Pipeline: Coalport to River Penk	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low	Low						

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
6.2	River Penk	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low	High	Moderate	Low	Low	Low	Low
6.3	River Sow	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High	Moderate	Moderate	Low	Moderate	Low
6.4	River Trent d/s of Gt. Heywood	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
6.5	BWB Canals–Heywood Jt. to Isis Lock	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	Low	Moderate	Low	Low	High	Moderate	Low	Low	Moderate	Low
6.6	River Thames d/s of Oxford Canal	High	High	Low	Low	Low	Low	High	High	Moderate	Low	Low	Low	Low	Low	Low	Low	Low	Low

RISK/OPPORTUNITY KEY:

HIGH	(black)
MODERATE	(dark shading)
LOW	(light shading)
NOT APPLICABLE	(white)

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

The fisheries, aquatic ecology and terrestrial impacts apply to all canal stretches.

5.6.1 Pipeline, Severn (Coalport) to River Penk

This component is discussed in Section 5.7.2.

5.6.2 River Penk to River Sow Confluence

This component is the same as that discussed in 5.7.3 Severn to Trent transfer option, therefore the environmental risks associated with this component are also the same.

5.6.3 River Sow to Trent and Mersey Canal

This component is the same as that discussed in 5.7.4, under the Severn to Trent transfer option, therefore the environmental risks associated with this component are also the same.

5.6.4 Trent and Mersey Canal, Great Heywood Junction to Fradley Junction

Hydrology

The major hydrological impact that would occur under the proposed transfer is an increase in flow velocity in the canal system. Care would need to be taken to minimise velocity increases to ensure the integrity of canal embankments and prevent bank erosion. However, there would be some environmental impacts related to this increase. The maximum velocity in canals is limited to 0.18 m/s. However, it has been calculated that under the transfer of 100 Ml/d the velocity would be between 0.1 m/s and 0.15 m/s. This figure rises to between 0.25 m/s and 0.31 m/s for canal sections beneath bridges.

Small changes in depth might occur as a result of increased flow and dredging. These are anticipated to be generally not greater than 100mm although this could rise to 250mm in places.

Water Resources

No impacts on water resources would occur for this component.

Water Quality

The differences in the mean of key water quality parameters of donor and receiving waters are summarised by Binnies (1993). However, no mass balance calculations have been undertaken at low flows or 95 percentile concentrations.

There are close similarities between the pH of the River Severn waters and those in the Trent and Mersey canal, 7.8 and 8.0 respectively.

However, there are differences in BOD, ammonia and suspended solids. The overall category of this canal reach is NWC Class 2 whereas the river is Class 1B. There is therefore a possibility of improving the canal water quality.

There is uncertainty over possible increased need for dredging both during and after construction and special care would need to be taken during construction phase to ensure the maintenance of water quality.

Fisheries (applies to all canal reaches)

All the canals involved in this study are subject to high boat traffic (74,000 movements per year). As a result of boat wash, there is resuspension of solid particles, which increases turbidity. Steel piling is needed to prevent excessive erosion of the banks in many areas. In general these canals can be characterised by high turbidity and little macrophyte presence.

The fish community is dominated by slowly growing roach and gudgeon, together with other species such as bream, perch, ruffe, pike, carp and on some sections zander, dace, and chub.

Biomass data is lacking for most of this route, but a value of 24 g m^2 was obtained for the zander free section of the North Oxford Canal. (cf 12 g m^2 for the zander populated section). The match fishery on the zander free section of the West Oxford is moderate and inferior to that of the Trent and Mersey, Grand union and Oxford Canals and the biomass density of these canals is expected to exceed 30 g/m^2. The Fazeley and Coventry Canals support moderate fisheries with an expected biomass density of 20-25 g/m^2.

The main impact of significance to fisheries would be associated with increases in flow along the canal system and consequent improvements in water quality. Although there are localised areas of pollution within the canal system, water quality generally is constrained by slow flows, high levels of suspended solids and wide fluctuations in dissolved oxygen. Increases in flow to the predicted level of 0.15 m/s would tend to create a highly favourable environment for coarse fish, with improved oxygen availability and less siltation.

Zander is a species introduced from Holland where it inhabits slow flowing drains and polders. Since its introduction to Britain, the species has colonised similar slow flowing waters in East Anglia and appears to have found a favourable niche in the Coventry and Oxford canals. Potential for introduction into the Thames and elsewhere already exists through river linkages but the species distribution has remained relatively restricted, possibly because of specific habitat requirements. Possible further spread of the species must be seen as a negative impact, and would warrant detailed investigation prior to development of this option.

Aquatic Ecology (applies to all canal reaches)

No specific data are available for the various canals except for the Oxford Canal which is on the NRA's National Database (1990). These data indicates a good in-stream fauna either Band A or B. BMWP scores range from 109 - 143.

In general a number of stretches are of in-stream ecological value and these would be affected certainly in the short term by dredging and possible release of contaminants. Discharge of water to the Thames is likely to be associated with water quality problems. The volume of water involved is relatively small compared to other transfers into the Thames but the impacts on the aquatic ecology of the Thames would need to be carefully investigated. Disposal of dredged material is also an issue.

Terrestrial Ecology/Planning (applies to all canal reaches)

There are a number of land use planning issues which would need further consideration if engineering works are to be undertaken along the full length of the canal reaches. These are detailed in the Binnie (1993) report.

The reach assessments show that certain stretches of the proposed water transfer route are covered by restrictive planning designations, including areas of landscape value, SSSIs, and sites of county wildlife value. The erection of buildings/pumping stations in the open countryside could prove problematic particularly in areas of Green Belt and "open countryside" designations. Lastly a number of stretches have considerable heritage value with locks and bridges being listed.

Part of Coventry Canal is within the Alvecote Pools SSSI and historic Alvecote Priory is sited immediately adjacent. The reach near Hawkesbury junction also includes a SSSI at Boons Quarry. A number of bridges along Coventry Canal are listed and would require listed buildings consent. A number of reaches also fall within a Special Landscape Area.

The Oxford canal is of high ecological value in a number of reaches, which could be adversely affected by dredging, and adjacent habitats include Barby Wood SSSI, Kirklington Quarry SSSI and Rushy Meadows SSSI. The canal through Rugby is defined as an "Amenity Corridor" which could be adversely affected in the short term by dredging. A number of Scheduled Ancient Monuments are located adjacent to the canal, and several stretches are located with areas of high landscape value.

Disposal of dredged material, general construction activity, bank raising and dredging itself would need to take these various designations on board. It should be noted that in general the proposed engineering work is of relatively small scale and could be integrated in a way which is consistent with planning policy. However, this might be difficult in some of the stretches.

Recreation/Navigation/Amenity

Transferring higher quality water into the canal is likely to improve the amenity and recreational value of the canal. However, there are uncertainties on the impact on fisheries due to the increase in velocities. Navigation would be unaffected.

Summary

The long term environmental risks associated with this component appear to be moderate. There are a number of stretches, however, that are covered by restrictive planning designations. Care will have to be taken during the construction phase to minimise impacts on water quality, particularly suspended sediment and the subsequent risks to fisheries, instream ecology, and recreation/navigation/amenity. Uncertainty exists over the extent of dredging required and the disposal of dredged material.

5.6.5 Coventry Canal, Fradley Junction to Hawkesbury Junction

Hydrology

The impacts associated with this component are the same as those presented in 5.6.4 above.

Water Resources

No perceived impacts on water resources would occur on this component.

Water Quality

The differences between the waters of the Trent and Mersey Canal and the Coventry Canal are unclear as no data are given in the summary report by Binnie & Partners (1993) however, this reach of the Coventry Canal is classified as NWC Class 2. This is the same as the upstream Trent and Mersey canal and if anything would be improved by the addition of River Severn water, categorised as NWC Class 1B, although the mixing by this stage of the transfer means that the benefits are likely to be minimal.

Fisheries/Aquatic Ecology/Terrestrial Ecology

The impacts associated with these components are the same as those presented in 5.6.4 above.

Recreation/Navigation/Amenity

The environmental impacts on this reach of the Coventry Canal are likely to be the same as those presented in 5.6.4 above.

Summary

The summary for this component is the same as that presented in 5.6.4 above.

5.6.6 Oxford Canal, Hawkesbury Junction to Isis Lock

For the purpose of this study, this reach is referred to as the Oxford Canal, however it does include a small section of the Grand Union Canal between Braunston turn and Napton Junction (length about 8 km).

Hydrology

The environmental impacts on this reach of the Oxford Canal are likely to be the same as those presented in 5.6.4 above.

Water Resources

No perceived impacts on water resources would occur on this component.

Water Quality

The main differences between the Oxford Canal and the Trent and Mersey Canal are the slightly higher mean temperatures in the Oxford Canal by about 1°C and lower mean ammonia levels. Comparing Oxford Canal water with that of the River Severn the main differences are: slightly higher temperatures in the Oxford Canal by 1.7°C, lower DO, higher BOD and total alkalinity although the pH is similar and higher TON, ammonia levels and suspended solids. The Oxford Canal is generally NWC Class 1B except for a section around Banbury where industrial discharge of vegetable oil has reduced the quality to NWC Class 2. The quality then reverts to Class 1B until the junction with the River Cherwell at Shipton where the quality deteriorates to NWC Class 2 and south of Kidlington sewage effluent causes further deterioration to NWC Class 3.

There are likely to be only minor water quality benefits from transferring River Severn water into the Oxford Canal bearing in mind that the water is being transmitted via the Trent and Mersey and Coventry Canals, both of which are NWC Class 2. Greater improvement would be afforded by reduction in industrial and sewage discharge into the canal.

Care would need to be taken during the construction phase to ensure the quality of this canal reach is not further reduced by an influx of sediment during engineering works.

Fisheries/Aquatic Ecology/Terrestrial Ecology

The impacts associated with these components are the same as those presented in 5.6.4 above.

Recreation/Navigation/Amenity

There is considerable recreation and amenity value to the northern part of this reach of the Oxford Canal and this is likely to be unchanged or slightly enhanced by transfer of similar or slightly higher quality water into the canal. However, the southern part of the canal has reduced recreation and amenity value due to effluent leaks and discharges. This part of the Oxford Canal reach would benefit from the transfer of higher quality water from the Oxford Canal north of Abingdon. Navigation would be unaffected, except possibly during any construction works. Care will need to be taken during construction phase to minimise any impact on the recreation/navigation/amenity value of this reach.

Summary

The summary for this component is the same as that presented in 5.6.4 above.

5.6.7 River Thames Downstream of Oxford Canal

The proposed transfer of 100 Ml/d into the Thames at Isis Lock is considerably less than the 400 Ml/d considered in previous transfer options. Many of the same comments apply, but the impacts in term of flow, velocity and duration would be of accordingly lesser magnitude.

The primary concern with this transfer, however, would be the final water quality discharged to the Thames. While the Severn water discharged to the Penk will be of Class 1B, water quality in the canal systems is Class 2 in many reaches and Class 3 in parts of the Oxford Canal. The canal water is likely to be eutrophic, with high levels of suspended solids. There is also concern that further contaminants could be derived from canal bed sediments.

The uncertainties concerning water quality, and the potential risk to aquatic ecology, fisheries, abstractions and recreation/amenity in the Thames, are such that this option appears much less environmentally acceptable than the other transfer/regulation schemes for the Thames.

5.7 OPTION 7: Severn to Trent Transfer

Description

This option was studied in detail by W S Atkins (1993). The engineering works involved are as follows:

- Intake works on the River Severn at Coalport.
- Highlift pump station at Coalport.
- Pipeline from Coalport to Lower Drayton on The River Penk comprising approximately 13 km of 1m diameter pipe, 13 km of 0.9m diameter pipe and 5 km of 0.8m diameter pipe (Route 1 in Atkins report).
- Balancing storage either at the start or end of the pipeline or at the watershed for 4 days transfer flow (possible use of Belvide Reservoir).
- Discharge structures at pipeline outlet into the River Penk at Lower Drayton.

Assumptions:

- Scheme operates on a put and take basis, supported by regulation of Severn, i.e., regulation matches abstraction.
- The River Severn regulated (by Vyrnwy or Llyn Clywedog).
- Maximum transfer capacity 100 Ml/d.

The summary environmental assessment for this option is shown in Table 5.7, and detailed assessments of each component are presetned in Appendix D.

5.7.1 Severn Upstream/Downstream of Coalport

This component includes the local impacts associated with the intake and the impacts on the reach upstream and downstream of the intake at Coalport. Table 5.7 summarises the environmental assessment.

General Character

The proposed intake is 6 km downstream of Buildwas gauging station with a catchment area of 3717 km^2. The river is already heavily regulated by reservoir releases and the Shropshire groundwater scheme. The channel is semi-natural downstream and an important feature of the landscape.

TABLE 5.7 Option 7 Environmental Assessment

OPTION 7.Severn to Trent transfer to supply East Midlands
TRANSFER: 100 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
7.1	Pipeline: Coalport to River Penk																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
7.2	River Penk																		
7.3	River Sow																		
7.4	River Trent d/s of Gt. Heywood																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

The channel between Buildwas and Coalport lies in the Ironbridge Gorge and much of the riparian land lies within the associated World Heritage site.

Hydrology

At the proposed intake location the River Severn is in the middle reaches of the River Severn situated on the flood plain, with water levels controlled by the natural channel regime.

The present mean flow (MF) at Buildwas is 5059 Ml/d and the Q_{95} low flow is 941 Ml/d. The minimum recorded mean monthly flow was 1013 Ml/d in July 1986. The mean annual flood is greater than 40,000 Ml/d. If a prescribed flow at Colwick gauging station in Nottingham on the River Trent is set at 2500 Ml/d the transfer would operate in two years out of three. If the prescribed flow at Colwick was reduced to 2050 Ml/d then the transfer would only be required one year in three.

With a maximum transfer rate of 100 Ml/d used on a put and take basis the effect on the low flow regime of the river both upstream and downstream of the intake would be negligible (less than 11% increase in Q_{95} upstream of the intake). If the scheme were not operated on this basis the worst case would be to reduce the downstream Q_{95} by 11%. This would have less impact on the River Severn than other the major regulated Severn-Thames transfers considered earlier, where transfer amounts are considerably greater.

Water Resources

Effects on abstractors downstream of the intake would be negligible as the scheme would be based on a put-and-take operation.

Water Quality

The River Severn at Buildwas is NWC Class 1B. There is negligible risk of causing changes to quality downstream.

Fisheries

The River Severn supports excellent fish stocks. Species composition include brown trout, chub, dace, gudgeon, pike, perch, roach and eel, but the river is renowned as an excellent salmon fishery and supports one of the largest runs in England and Wales, second only to the River Wye.

Sites just upstream of the abstraction point at Coalport including Atcham, Cressage and Buildwas (between Shrewsbury and Telford) were sampled in July 1992. The populations include salmon, trout, chub, dace, gudgeon, bream, pike, perch, roach, eel, barbel and grayling.

In 1992 sites downstream of Coalport (Quatford, Hampton Loade, upper Arley and Stourport) included chub, dace, gudgeon, pike, perch, roach/and eel. There are unlikely to be adverse effects on the River Severn since the transfer would operated on a put and take basis, based upon regulation of the Severn using present regulation sources.

Care must be taken in design of the intake to minimise fish entrapment.

Aquatic Ecology

The macroinvertebrate population is sampled at a number of sites around Coalport. Two upstream sites Atcham (SJ54000920) and Cressage (SJ59400460) have BMWP scores of 152 and 177 respectively. The number of taxa at Atcham was 28 and the ASPT 5.4. Predicted scores for both sites is 197 with an ASPT of 6. The number of taxa at Cressage was 32 with an ASPT of 5.5. Both sites are classified as biological class A indicating excellent quality. Two sites downstream of Coalport, Bridgenorth and Bewdley support excellent communities with BMWP scores of 161 and 215 respectively and ASPTs of 5.6 and 5.8 respectively. Predicted BMWP scores were in the region of 197. Both sites have been classified as biological class A. As with fisheries, the transfer is unlikely to have adverse effects on the River Severn.

Terrestrial Ecology

The intake location would affect a wooded gorge, although sympathetic construction and reinstatement should mitigate most of the impacts.

Recreation/Navigation/Amenity

The River Severn is navigable upstream of Coalport and has considerable amenity value in this area. Watersports and angling both occur along this reach of the river. Increased low flows could have moderate benefits for amenity and recreation use.

Summary

Whether this 100 Ml/d scheme would be operated on a put-and-take basis as considered here, or even by transferring a proportion of natural flows, there would not appear to be any significant environmental risks associated with this component.

5.7.2 Pipeline, Coalport to Lower Drayton on River Penk

General Landuse Planning

Route 1 runs north eastwards from the intake downstream of Coalport Bridge just to the north of Cosfield Airfield. From there it heads just north of Bilride reservoir and then on a direct line north of Penk ridge to a discharge point into the River Penk at lower Drayton.

There are a wide range of sites, areas and landscape features that are afforded some degree of classification. Detailed investigation of the proposed route alignment would be needed at a later stage. Route 1 crosses the River Worfe catchment which is designated as a area of Special Landscape Character.

The majority of site-specific planning constraints could be avoided. Overall, the potential impacts associated with provision of a pipeline are predominantly temporary and relate to construction activity. Appropriate restoration measures would have to be undertaken along all route sections and restoration of habitats to 'pre-scheme' conditions must be specified.

Water Quality

It has been estimated that the travel time for water in the pipeline would be about 8 hours. During periods when the transfer is not taking place consideration would have to be given to how the pipeline is drained down and the water discharged. Other potential quality risks associated with the pipeline are out-gassing, scaling, and corrosion. The use of balancing storage ponds sufficient to hold 4 days transfer located along the pipeline route should reduce any suspended solids, however, if residence times are considerable, this may have water quality implications.

Summary

While there are moderate water quality risks associated with intermittent pipeline transfers, these could be overcome by design and operational measures. The impacts associated with infrastructure development should be mitigable through careful planning, design and construction, following detailed fieldwork and consultation.

5.7.3 River Penk, Lower Drayton to Confluence with River Sow

Hydrology

The present mean flow at Penkridge gauging station on the River Penk is 194 Ml/d and the Q_{95} low flow is 60 Ml/d. The minimum recorded mean monthly flow was 30 Ml/d in August 1976. The mean annual flood is greater than 1000 Ml/d. Assuming a PF at Colwick of 2500 Ml/d, this scheme would operate over the summer months once every four years on average.

If 100 Ml/d is transferred into this river, representing 267% of the Q_{95} discharge, then this would have a significant impact on the low flow regime, resulting in increased depth and velocity over the summer. Hydrological analysis by Atkins (1993) indicates that transfer would be most likely to occur from June to October. Although the transfer of 100 Ml/d would increase discharge and depth during low flow months, these would remain within the natural range of variation of the channel, but there would be a change in the seasonality of the flow regime. The Penk has recently been subjected to significant channel improvements, which will to some extent mitigate the effects of the flow changes.

Water Resources

No impact on water resources is anticipated as a result of the transfer.

Water Quality

There may be benefits from transfer of NWC Class 1B Severn water into the lower quality River Penk, categorised as being NWC Class 2. The target RQO for the Penk is 1B, and this is likely to be achieved soon due to effluent improvement.

Fisheries

The transfer would cause a doubling of the Q_{95} flow in the Penk. The high flow regime would remain unaffected hence risks of washing out of fry would not be increased. Impacts on locally important coarse fisheries in the Penk are likely to be generally positive, due to changes in low flow characteristics and some improvements in water quality.

Aquatic Ecology

Very limited data are available for the Penk. However, data for two sites, Penkridge and Stafford record indicated that the biological band is C, of moderate to poor quality.

This option would have a major local beneficial impact upon the Penk, a small stream with a natural flashy flow regime.

Terrestrial Ecology

No data were available during the course of the study. However, further channel engineering works would not be needed therefore significant effects on terrestrial ecology are not foreseen.

Recreation/Navigation/Amenity

There would be likely to be an improvement of amenity value of the River Penk as a result of the transfer.

Summary

W S Atkins (1993) concluded that there were no significant environmental risks associated with this component. Careful consideration should be given to ensure velocity increases in the River Penk do not result in scour.

5.7.4 River Sow, from River Penk Confluence to River Trent Confluence

Hydrology

The mean flow for the gauging station at Milford (closed 1977) is 447 Ml/d and the Q_{95} low flow is 124 Ml/d. The minimum record mean monthly flow was 86 Ml/d in April 1976. The mean annual flood is greater than 2700 Ml/d. The effects of transferring 100 Ml/d into this reach would be similar to those experienced by the River Penk upstream.

Water Resources

No impact on water resources in this river section is expected to arise from the transfer.

Water Quality

There would be considerable benefit from transfer of NWC Class 1B Severn water into the lower quality River Sow, categorised as being NWC Class 2.

Fisheries

The Sow is a locally important coarse fishery, and the increased flows and associated quality improvements would be expected to have generally positive effects on the fish stocks.

Aquatic Ecology

Invertebrate communities on the River Sow achieve a biological class of B for much of the river's length. Class C is observed at Milford on the Sow, reflecting the influence of sewage effluent.

Low flow augmentation on the River Sow, which drains a low relief agricultural catchment, would be likely to be highly beneficial, sustaining a diversity of instream habitats.

Terrestrial Ecology

There were no data available for this stretch of river during this study. However channel engineering works would not be required and therefore no significant impacts are foreseen.

Recreation/Navigation/Amenity

There would be likely to be improvement of amenity value of the River Sow, particularly visually. The amenity value of the Sow/Trent confluence is important bearing in mind the close proximity of the Shugborough Estate owned by Lord Lichfield which is open to the public.

Summary

W S Atkins (1993) concluded that there were no significant environmental risks associated with this component. Risks associated with fisheries should be investigated further. Careful consideration would have to be given to the discharge rate to ensure any velocity increases do not result in scour thus destroying the pool and riffle structure of the river.

5.7.5 River Trent Downstream of River Sow Confluence

This component includes the local impacts associated with the discharge and the impacts on the reach downstream of Great Heywood.

General Character

The River Sow enters the River Trent at Great Heywood just downstream of the gauging station at Great Heywood. The catchment area to the gauging station is 325 km^2. The catchment is semi-natural and an important feature of the local landscape. The riparian land at the confluence of the River Sow with the River Trent lies within the boundary of Shugborough Park, the estate owned by Lord Lichfield which is open to the public.

Hydrology

Only a short record exists between 1957 and 1964 for the gauging station at Great Heywood. The mean flow at Great Heywood is 384 Ml/d and the Q_{95} low flow is 200 Ml/d. The minimum month flow recorded is 160 Ml/d in September 1964. The mean annual flood is greater than 2500 Ml/d.

With a maximum transfer of 100 Ml/d the effect on the River Trent downstream of the transfer represent a 50% increase to the Q_{95} low flow which is likely to have a depth impact rather than a substantial velocity impact. However, the transfer would be within the natural range of variation within the river.

Water Resources

No adverse impact on water resources is expected to result from the transfer.

Water Quality

The transfer of NWC Class 1B Severn water into the lower quality River Trent, categorised as NWC Class 2, would be generally beneficial. However, there are particular water quality considerations to be taken into account. River Severn water is significantly lower in alkalinity and hardness (61 to 240 Mg/l total hardness in Severn whilst in Trent can exceed 560 mg/l) as are concentrations in TON (95 percentile 11.5 mg/l in Severn and 95 percentile 12.6 mg/l in Trent). Both BOD and ammonia levels are likely to be reduced in the Rivers Penk and Sow during the transfer. The 95 percentile values for BOD and ammonia in the River Severn are 5.8 mg/l and 0.72 mg/l, and in the River Trent they are 8.6 mg/l and 0.73 mg/l respectively.

Fisheries

The River Trent supports a good coarse fish population and is a designated EC Cyprinid Fishery for much of its length (Directive 78/659/EEC). Species found in the upper reaches include chub, dace, roach, gudgeon, eel, bream, pike and brown trout. The river is intensively used for angling.

Minor impacts on flow and water quality in the upper Trent are likely to be beneficial. The fish disease *Pomphoryncus* occurs in the Severn but not in the Trent. Although the disease has become fairly ubiquitous in Britain, its absence from the Trent is thought to be due to scarcity of the intermediate host, *Gammarus*. Although the NRA policy is to avoid transfers of infected fish, the disease is not thought to have caused fish mortalities elsewhere. In the absence of any pathogenic evidence to the contrary, the disease is unlikely to be a critical issue.

Aquatic Ecology

The biological class at Great Heywood (SJ99502300) is classified as C, of moderate/poor quality. Data from the National Data Base (1990) show that BMWP score was 49, with 13 taxa and an ASPT of 3.8. All of these are well below those predicted by RIVPACS, the predicted BMWP being 184.7, with 31 taxa and an ASPT of 5.9. Biological quality improves downstream where the BMWP score at Colwich is 95 and the biological class is B. Between Colwich and Burton-upon-Trent the river is either classified as B or C.

The minor impact on low flows within the upper Trent is likely to be beneficial, maintaining a diversity of habitats during drought years.

Terrestrial Ecology

No significant impacts from the transfer are foreseen.

Recreation/Navigation/Amenity

Although the River Trent is not navigable along the reach near Great Heywood the river is used for watersports and coarse fish angling. The river has considerable local visual amenity value, and the improvement in low flow and quality will be beneficial.

Summary

There do not appear to be significant environmental risks associated with this transfer component. Attention should be given to limiting any velocity increases in the River Trent during the transfer periods and avoid scour or affects on navigation.

5.8 OPTION 8: Great Bradley Reservoir with Ely Ouse-Essex Scheme

Description

This option was studies in detail by Atkins (1993). The engineering works involved are as follows:

- Dam impounding the upper Stour valley near Great Bradley and Weston Green villages and below inflow from Ely Ouse-Essex scheme outfall.

- Possible upgrading works on transfer pipelines, pumping station, outfalls and intakes as the Ely Ouse-Essex transfer scheme.

Assumptions:

- No transfers into Thames Region.

The summary environmental assessment for this option is shown in Table 5.8, and detailed assessment of the components is presented in Appendix D.

5.8.1 Great Bradley Reservoir

The project would consist of a main dam near Great Bradley, diversion, drawoff and spillway arrangements and a subsidiary dam for the protection of Weston Green. The reservoir would provide strategic storage as part of the regional strategy to transfer water from the Ely Ouse to the Essex rivers. Inflows to the reservoir would be principally from an upgraded Ely Ouse transfer scheme. The outlet from Great Bradley would be to the River Stour. Two reservoir options were examined by W S Atkins (1993), a larger reservoir with a top water level of 105.5m AOD, selected for discussion here, and a smaller reservoir with a top water level of 99m AOD.

Agriculture Land Use

The environmental implications of a top water level of 105.5m AOD would be considerable. The dominant land use in the upper Stour area is arable Grade 2 (MAFF Agricultural Land classification). An area of Grade 3a lies in the valley bottom upstream of Great Bradley. This would represent the 'best and most versatile' agricultural land, and MAFF would need to be consulted on the scheme. Although the Planning

TABLE 5.8 Option 8 Environmental Assessment

OPTION 8. Great Bradley Reservoir – Ely Ouse to Essex Transfer
TRANSFER: 309 Ml/d max.

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
8.1	Great Bradley Reservoir *																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
8.2	Tidal Ely Ouse to The Wash																		
8.3	River Stour																		
8.4	River Pant/Blackwater																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

Notes:
* Impact would be significantly less for smaller/lower reservoir

Policy Guidance Note PPG7 states that 'the increasing efficiency of agricultural procedures and changes in agricultural policy mean that retaining as much land as possible in agricultural use no longer has the same priority' PPG7 still confirms the need to conserve the best land as a long term valuable agricultural resource.

Landscape

The area of interest is designated as an 'Area of Best Landscape' and the project would therefore have moderate impacts on existing landscape quality. In addition the upper Stour Valley comprises an "Ancient Countryside" with ancient hedgerows and woodland. It should be noted that this type of landscape is unusual in Cambridgeshire. The visual impact on local communities is considered high due to the proximity of the dams to the villages of Great Bradley and Weston-on-the-Green.

Nature Conservation

The nature conservation implications of the scheme are also of concern. Four Sites of Special Scientific Interest (SSSI) would be lost to the scheme, all being ancient woodlands, and a further 5 ancient woodlands of nature conservation value would also be affected. This loss is significant for several reasons; firstly it is impossible to recreate these woodlands, and secondly ancient woodland are rare in Cambridgeshire. Other sites of nature conservation value are present within the area (although the significance of these is not clearly defined within the study report on this option - WS Atkins, 1988). In addition some of the remaining woodlands could be indirectly affected as a result of altered hydrology.

Archaeology

There are no Scheduled Ancient Monuments within the area although 17 sites of archaeological interest would be affected. It is likely that more sites would be identified by field surveys. Five listed buildings would be inundated and a further listed building could be affected.

Community Impacts

Perhaps, the most significant impacts relate to the loss of a total of 77 properties, 53 of which are residential, 14 agricultural and 10 are classified as 'others'.

Construction of the reservoir, particularly the dams at Great Bradley and Weston Green could have significant adverse effects on the environment. Impacts of particular concern would include noise, traffic and dust. The construction of the Brinkley Western bypass, and the new diverted B1061, and its associated spurs and upgrading of C231 would also result in impacts.

Recreational impacts include loss or diversion of public rights of way and visual impacts on rights of way that would remain after development.

Potential for Mitigation

As ancient woodland cannot be recreated (Kirby 1992), each being a unique response of possibly thousands of years, it is extremely difficult, to mitigate for its loss. Partial mitigation measures could include woodland planting, which with appropriate management could in time become valuable habitats. Landscape proposals would partially mitigate some of the landscape and visual impacts.

Opportunities for Enhancement/Recreation-Amenity

There are considerable opportunities for recreational enhancement with provision of amenity areas, angling, sailing and nature trails. Rutland Water has become an important contributor to the local economy of the surrounding area and similar benefits could arise for this region. The benefits however would need to be considered in light of increased traffic generation in what is presently a quiet remote area.

Summary

Construction of the reservoir with a top water level of 105.5m AOD would have considerable environmental implications, both from a community impact and nature conservation perspective. The smaller reservoir with a top water level of 99m AOD would have a significantly smaller risk of impact.

5.8.2 Ely Ouse Downstream of Denver

The Ely Ouse would be the source of the water for Great Bradley, with transfer via an upgraded Ely Ouse-Essex transfer scheme. The additional abstraction would have impacts on the Tidal River below Denver Sluice, the Great Ouse estuary and the Wash.

General Character

Denver Sluice is the point at which water is diverted from the Ely Ouse into the cut-off channel for transfer to Essex. The catchment area is 3430 km^2. Flows into the Tidal River are already heavily affected by abstractions in the Ely Ouse and Bedford Ouse catchments for direct supply and reservoir storage, and for the existing Ely-Ouse - Essex transfer scheme. The Tidal River is channelised and dredged and has a semi-natural character.

The Wash is an important area nationally, and is a major Site of Special Scientific Interest and is recognised as being of international significance under the RAMSAR convention. The Ouse Washes are a seasonally flooded grazing marsh and is also a SSSI and RAMSAR site.

Hydrology

The characteristics of the Tidal River are dominated by the tidal cycle.

The present mean flow (MF) is 1417 Ml/d at Denver sluice (Binnies 1993), and the Q_{95} low flow is 175 Ml/d. The minimum recorded monthly flow is 0 Ml/d in August 1976. Over the last twenty years since the introduction of the Ely Ouse-Essex Scheme, the transfers have averaged 32 Ml/d or 2%, but the scheme is used heavily in dry years, for example in 1991 the mean flow fell to 475 Ml/d and the amount transferred averaged 126 Ml/d. The present minimum residual flow for the Ely Ouse-Essex Scheme is 114 Ml/d between March and August and 318 Ml/d between September and February.

Under this MRF potential restrictions on transfers are common (>25% of years) from June to November, and abstraction would not be possible in August and September for between 10 and 20% of years respectively.

The current Ely Ouse-Essex scheme has a maximum capacity of 454 Ml/d. Binnies (1993) have examined the possible effects of increasing the capacity to 772 Ml/d on the introduction of Great Bradley reservoir, and of reducing the MRF. Transfers, supported by storage at Great Bradley, would only take place when there was insufficient water in the Essex rivers to replenish existing reservoirs (adjacent to the rivers) from local resources. Reducing the MRF would be likely to result in more water being taken in July to November when transfers are potentially most often restricted at present.

Water Resources

Reduction in freshwater flow could lead to intrusion of saline water further inland, particularly during spring tides, and this could affect abstractions in the estuary for irrigation, and increase the likelihood of saline water entering ditches fed from the New Bedford River and used for irrigation. Mitigation measures such as use of freshwater releases could be introduced, but overall protection will depend on setting a suitable minimum residual flow.

Water Quality

The present MRF appears to be related to provision of dilution flows for domestic and industrial effluents from Kings Lynn. Retention of the MRF will protect existing water quality standards, particularly during low flows, although there are likely to be some changes in water quality in the Tidal River and the south eastern Wash. Changes in freshwater flow could affect the movement of bacteria from Kings Lynn sewerage works into the Wash, potentially affecting the variety of shellfish and shrimp fisheries.

The freshwater flows into the Tidal River form a major component of the inflow to the Wash. Additional transfer to Essex may cause the salinity of the Wash to rise very slightly closer to that of the southern North Sea. This will be most pronounced in the south east corner. These changes, together with additional saline intrusion into the Tidal River, could affect the complex and important ecosystems in these areas.

Fisheries

The Tidal River system is used by migratory fish, particularly eels, which are harvested commercially, and sea trout. Deterioration in estuary water quality could adversely affect the fishery, but protection could be provided by proposed water quality standards for the estuary and setting of a suitable MRF.

Sluice operation involved in the scheme will need to take account of the possible impact on migratory fish. The upper part of the New Bedford River supports a good summer coarse fishery although its extent is naturally limited by occasional high salinity. It would be adversely affected by any increase in saline intrusion.

Shell fisheries within the Wash are presently contaminated with bacteria to the extent that all mussels harvested in the Wash have to be purified before sale for human consumption. Reductions in freshwater flow would not change the numbers of bacteria entering the Wash but might alter their distribution.

Changes in the freshwater flow, linked to temperature, could perhaps affect cockles and mussels, but these issues are poorly understood at present.

Increases in salinity in parts of the Wash during low flow periods have been reported as enabling predatory fish such as whiting to come further inshore and feed on shellfish and shrimps. These changes could be increased by additional transfers out of the Ely Ouse catchment.

Yields of brown shrimp have declined in recent years and this has been attributed to build-up of concentrations of potentially toxic substances in the ecosystem. Reductions in freshwater flow could increase the perceived problems. Further work is required to investigate this issue.

Aquatic Ecology

The Tidal River and the low water channels running out into the Wash are severe environments with large fluctuations in flow and salinity and are of little value from an ecology viewpoint. Changes in these parameters and siltation will have little impact save that water quality is suitable for passage of migratory eels and sea trout.

The Wash comprises a complex system with a diversity of estuarine fauna including invertebrates and fish, birds, especially waders, and seals. Water quality factors are of most concern. Although total flow of nutrients, bacteria and potentially toxic substances would remain relatively unchanged, the concentrations and distributions would be affected and the possible effects need to be investigated.

Terrestrial Ecology

The Ouse Washes and the Wash are SSSI's and RAMSAR sites designated under the convention on wetlands of international importance. The Wash is also designated as a Special Protection Area under the EC Directive on conservation of wild birds.

The Ouse Washes are related to conditions in the Bedford Ouse system, and only indirectly to the MRF on the Ely Ouse. Increased sedimentation in the estuary could lead to enhancement of present flooding problems with drainage of floodwater and shortening of period for livestock grazing and bird nesting.

Increase in entry of saline water into the drainage ditches could have adverse effects on flora and fauna and on grazing.

There could be some impact on the marginal zones of the rivers and drains, but these have not been identified as being of special significance.

Recreation/Navigation/Amenity

Sailing, wind surfing and canoeing are unlikely to be affected by reductions in freshwater flow. However, increased sedimentation could be of significance to barge/cruiser traffic, particularly at Denver Lock in transfer from the Ely Ouse to middle level navigations. Mitigation would be possible by selective operation of Denver sluice to clear sand bars, as is done at present. Impacts on angling were discussed earlier.

The estuary downstream of Kings Lynn is used as a navigation channel for commercial shipping docking at Kings Lynn. The Wash shipping channel is constantly changing alignment and the bed of the estuary is the approach to Kings Lynn is one constraint on the draft of vessels able to use the port. Increased frequency of high bed levels, likely to result from additional transfers to Essex, would lead to access problems for larger shipping. There could also be impacts on the passenger ferry across the Tidal River at Kings Lynn. This could perhaps be mitigated by additional dredging.

Flood Defence

Flood defences around the Tidal River and the Barrier Banks around the Great Ouse are linked to assumed estuary bed levels. Siltation arising from reductions in freshwater flows could result in higher flood levels with an increase in the risk of overtopping the defences. It might be possible to mitigate this by use of selected releases and operation of sluices.

Summary

The Tidal River, estuary and the Wash could be affected by increased abstractions in terms of water resources availability, water quality, fisheries including shell fisheries, aquatic ecology particularly the Wash which is of international importance, recreation, amenity, navigation and flood defence. All of these concerns could be met by the setting of an appropriate minimum residual flow at Denver sluice, following detailed studies.

5.8.3 River Stour Downstream of Reservoir

General Character

The Stour is of semi-natural character running through gendy undulating chalk downland, primarily under arable agriculture.

Hydrology

The hydrology of the catchment is heavily influenced by the existing Ely Ouse-Essex transfers. Mean flow at Kedington (catchment area 76 km^2), 7 km downstream of Great Bradley, is 58 Ml/d, the Q_{95} low flow is 3.5 Ml/d and minimum monthly flow 1.7 Ml/d recorded in August 1976. Bankful discharge taken as Q_{10} is 147 Ml/d. The Stour at Lamarsh (catchment area 480.7 km^2) has a mean flow of 207 Ml/d, a Q_{95} low flow of 52 Ml/d and a minimum monthly flow of 19.8 Ml/d in August 1976. Bankful discharge taken as Q_{10} is 406 Ml/d.

The outlet from Great Bradley has been sized to pass 534 Ml/d. The present capacity of the Ely Ouse-Essex scheme which discharges to the Stour is 334 Ml/d. These discharges would dominate the hydrology of the catchment and lead to a change in seasonality of flows. Binnies have examined the implications of increasing the throughput of the existing Ely Ouse-Essex scheme and concluded that the upper Stour is capable of taking up to the current licensed maximum of 454 Ml/d, with minor channel improvements which in part make good dereliction since the scheme was built. Discharges above this would need to be piped to Wixoe.

Water Quality

The Stour water quality characteristics are influenced by high chloride and conductivity values of existing Ely Ouse transfers. Anglian NRA consider the observed high conductivity and chloride values in 1976 and 1991 to be due to leaking gates on the Ely Ouse, and that ingress can/has been controlled by engineering and management. In the vicinity of Wixoe the river is assigned NWC Class 2, RQO F2/LW/MA. Poor water quality is characterised by:

- conductivity and chloride levels frequently above values set for spray irrigation (produced in-catchment and by transfers);
- maximum nitrogen values more than twice the value acceptable for potable water supply abstraction (mainly produced in-catchment).

Nitrates are particularly a problem during springtime, probably due to agricultural usage in the catchment although there is some loading from Ely Ouse transfers.

Additional flows in the Stour due to releases from Great Bradley could improve water quality, due to the effects of storage in the reservoir, blending and improved timing of releases. However, the Ely Ouse provides a high nitrate water, with risk of high chlorides depending on timing of transfers, subject to the comment above.

Given the limited inflow to Great Bradley from the Stour, the water quality within the catchment would correspond to the Ely Ouse water, modified by storage, and perhaps treatment for nutrient removal (Atkins, 1993). There would be likely to be some improvement in quality from the present Class 2, with most improvement in present low flow periods.

Water Resources

Availability of water releases from Great Bradley to regulate summer flows could allow demands for abstraction to be met. However, conductivity levels and chloride levels might be too high for spray irrigation of certain sensitive crops, depending on water quality in the Ely Ouse at the time of transfers.

Aquatic Ecology

The macroinvertebrate communities at Great Bradley Hall bridge (TL67605325) are classified as moderate to good. The BMWP scores is 94 with 21 taxa yielding an ASPT of 4.5. Sites further downstream from Little Thurlow to Flatford Mill Footbridge are all classified as band A, with BMWP scores ranging from 83 to 187 and ASPT ranging from 4.2 to 5.3.

There is however some evidence to suggest that the Stour has been adversely affected by intermittent transfers from the existing Ely Ouse schemes which have resulted in scouring of vegetation and bed material. Effects could be potentially greater with the Great Bradley releases, but could be mitigated to some extent by channel design and control of flow changes. An environmentally sensitive approach to channel modifications could improve the range of habitats available.

The proposed transfer would change the aquatic ecology from that of a small headwater stream to that of a middle-order river; this has already occurred to some extent with the present Ely Ouse-Essex scheme. The impact on the aquatic ecology at the regional scale will be small because there are many other similar streams but the impact upon the landscape would be considerable with the new river becoming a prominent feature. Public perception as to whether this is of positive or negative value is likely to be mixed.

Recreation/Navigation/Amenity

The upper reaches of the Stour have considerable amenity value although between Kirtling Green outfall and the Wixoe intake the river is not navigable.

There are numerous footpaths and bridal paths used by local people together with angling along this reach of the Stour. Indeed, there are plans to develop the amenity value of this reach of the river, possibly to include a canoe slalom at Kirtling Green outfall. Great care would be needed to minimise disruption and reduce the effects on water quality during any river improvement works which would certainly be required to increase the capacity of the channel. Uncertainty exists over the effects on water quality and angling by further disrupting the natural flow pattern in this river.

The impact on amenity is likely to be variable. Benefits to water sports from increased flows would need to be offset against possible detrimental effects on fisheries and additional scour and bank erosion.

Summary

This river is already heavily regulated by the Ely Ouse-Essex transfer scheme, with transfers over 100 x Q_{95}. The introduction of storage at Great Bradley would be likely to improve water quality because of the timing of transfers, modification within the reservoir and timing of releases. The even higher releases from Great Bradley could result in further scouring of the channel and washout of biota, although operational control rules minimising flow changes would mitigate some of the effect. Channel improvements could be used to improve the ecological character of the river, enhancing habitats and landscape. Flow and quality changes would dramatically alter aquatic ecology, fisheries and landscape from the natural conditions, but would improve the present conditions produced by regulation. Further studies and investigations are required.

5.8.4 River Pant/Blackwater

General Character

The River Pant has had channel improvements made over recent years and has a man-made character below the Great Sampford discharge point.

Hydrology

The hydrology of the River Pant/Blackwater is already regulated by existing Ely Ouse-Essex transfers, with releases taking place at Great Sampford. The mean flow at Copford Hall gauging station (catchment area 62.5 km^2) is 30 Ml/d, with a Q_{95} of 1.7 Ml/d, and maximum water flows of about 250 Ml/d. Further downstream at Stisted (catchment area 139.2 km^2) the River Blackwater has a mean flow of 65 Ml/d, a Q_{95} flow of 13.8 Ml/d and minimum monthly flow of 6.9 Ml/d. The proposed transfers would change the seasonality of flows.

Proposed maximum transfers of 305 Ml/d appear in excess of the bankful capacity of the Pant/Blackwater at the points described above (using Q_{10} as an indicator of bankful conditions, these flows are 86 Ml/d and 130 Ml/d respectively), and at Longford (catchment area 337 km^2 a Q_{10} flow of 250 Ml/d). Extensive channel changes would therefore be required throughout most of the river length to take the flows passing to the Essex reservoir intakes. Modelling by Binnie (1993) suggests that to pass 364 Ml/d, about 20% of the banks between the Sampford discharge and Weathersfield, 13 kms downstream, would need to be raised by an average of 0.75m.

The River Pant downstream of Great Sampford has already been the subject of channel improvements and WS Atkins (1993)suggest that an environmentally sensitive approach to channel modifications could improve the character and general ecosystem value.

Water Quality

Like the Stour, the Pant/Blackwater water quality is already influenced by Ely Ouse transfers with elevated chloride values of up to 387 mg/l, due to leaking gates on the Ely Ouse (note however NRA comment in 5.8.3). Overall, water quality is assessed as NWC Class 1B with RQO F1/SI/LW/MA. Nitrogen levels are substantially lower than in the Stour.

Additional transfers to the Pant/Blackwater via Great Bradley would be likely to raise nitrate levels (high in Ely Ouse), and chloride levels depending on the timing of transfers and engineering/management of sluice gates on the Ely Ouse. No change is expected in un-ionised ammonia levels. The transfer discharge quality would dominate the system with Ely Ouse water altered by any modification on blending and mixing in Great Bradley reservoir.

There would be likely to be some improvement in quality from the present conditions produced by intermittent regulation and agricultrual run-off.

Fisheries

The River Pant/Blackwater is mainly a chub/dace fishery, with most reaches classified as Class A fisheries based on biomass and population density. However, reaches upstream of Bardfield Mill (which supports limited trout population) are only Class D, largely due to natural and possibly man-made flow changes. Coarse fisheries could be improved, in terms of water quality, by regulation from Great Bradley, although the water quality changes likely within the reservoir need further study.

Similarly with the Stour, algal blooms arising from Ely-Ouse transfers could cause large scale fluctuations in diurnal oxygen, significantly raising BOD and cause clogging of gill structures of fish. Such blooms could be prevented by appropriate management of Great Bradley reservoir.

Significant changes to the coarse fishery could, however, arise from the changes in hydrology and water quality. Channelisation of the river would also have a significant impact, particularly during the construction phase. Flow related effects could be mitigated to an extent by ensuring changes in flow occur over a period sufficient for fish to adapt.

Aquatic Ecology

Data are available for three sites on the Pant, approximately 70m downstream of Great Sampford bridge, Little Sampford bridge and Wethersfield Mill road bridges. All sites are classified as being in band A. BMWP scores are 119, 117 and 161, indicating a good invertebrate fauna.

The River Pant has been heavily channelised and has an artificial character. However, the proposed transfer/regulation would increase low flows to near bankfull levels with major impacts upon channel stability and aquatic ecology. Water quality changes could also be significance.

The Pant may have been adversely effected by intermittent transfers from the Ely Ouse scheme which has resulted in scouring of bed material and vegetation. The potential for this to occur will increase with the proposed transfers but could be mitigated to some extent by sufficient operating control over rates of flow change.

Algal transfer with the existing Ely Ouse-Essex scheme has been problematic with bloom proportions of *Stephanodiscus* occurring periodically in the Stour. Similar problems could develop in the Blackwater as in the Stour, contributing to a decrease in the growth of macrophytes, but the management of Great Bradley could be used to mitigate this.

Recreation/Navigation/Amenity

Landscape, general character and amenity could be significantly enhanced by adoption of an environmentally sensitive approach to channel modifications. However, there could be changes in the angling prospects, with conditions farrowing species preferring higher flows.

Summary

As with the River Stour, the Pant/Blackwater is already heavily regulated by the Ely Ouse-Essex transfer scheme (over 100 x Q_{95}). The summary given in 5.8.3 applies here also. Raising of the banks by around 0.75m would be needed over substantial distances. Although the opportunity could be used to improve the character of the river, there would be a major impact on ecology, fisheries and landscape. The reservoir would however, improve flow variability and quality from the conditions created by the present Ely Ouse-Essex scheme.

5.9 OPTION 9: Unsupported Trent to Essex Transfer

This option was studied by WS Atkins (1993). The engineering works associated with this transfer option are as follows:

- Upgrading pumping capacity at Torksey pumping station to handle additional 200 Ml/d giving total nett daily transfer of 420 Ml/d (peak flow to allow for pump restrictions at high tide 571 Ml/d) of which 220 Ml/d is already transferred to the River Ancholme from the River Witham at Short Ferry pumping station. Current Torksey capacity is 185 Ml/d nett over the day.

- Possible bank raising, bank protection, raising bridges on Fossdyke Navigation.

- Construction of intake at Boston (Langrick Bridge) on River Witham and 57 km pipeline to Denver Sluice (Route 2.1m WS Atkins (1993) report).

- Possible upgrading of Blackdyke intake and tunnel to Kennet pumping station

- Possible upgrading of Kennet pumping station to handle additional flows

- Possible upgrading of Kirtling Green Outfall

Under this option a maximum of 200 Ml/d would be transferred from the Trent (unsupported) to Essex.

Assumptions:

- Great Bradley reservoir not included and no transfers into Thames region.
- Prescribed flow on the Trent of 2,500 Ml/d to meet downstream needs, including migratory salmonids.

The summary environmental assessment for this option is shown in Table 5.9, and detailed assessment of the components is presented in Appendix D.

5.9.1 River Trent Downstream of Torksey Intake

Hydrology

The existing intake at Torksey is located about 30 km downstream of the gauging station at North Muskham. The catchment area to North Muskham gauging station is 8231 km^2. The intake at Torksey lies in the lower reaches of the River Trent. At this location the Trent is tidal with a depth velocity regime dominated by the tidal cycle. The intake may be within the zone affected by saline intrusion. The tidal limit of the River Trent is Cromwell weir, just downstream of North Muskham.

The present mean flow at North Muskham is 7746 Ml/d and the Q_{95} low flow is 2402 Ml/d. The minimum recorded monthly flow was 1674 Ml/d in August 1976. The mean annual flood is greater than 48,000 Ml/d.

The maximum transfer rate of 200 Ml/d thus only represents 8% of the Q_{95} low flow. A provisional prescribed flow of 2,500 Ml/d has been put forward by NRA Severn Trent Region in order to protect downstream needs including migratory salmonids. Considerably more work is required before this figure can be verified.

Water Resources

Cottam and West Burton power stations are situated downstream of the Torksey intake. These power stations are licensed to abstract 227 Ml/d and 218 Ml/d respectively on a put and take basis. This represents about 20% of the Q_{95} low flow. There are not known to be any other major abstractors downstream of the Torksey intake which might be derogated as a result of the transfer. Keadby power station once constructed will be licensed for 984 Ml/d also on a put and take basis and with no derogation rights. As discussed earlier Torksey is already an abstraction point for transfer of water via the Fossdyke Navigation to

TABLE 5.9 Option 9 Unsupported Trent to Essex

OPTION 9. Unsupported Trent to Essex
TRANSFER: 200 M/d

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
9.1	Pipeline: Witham to Ely Ouse																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
9.2	Trent d/s of Torksey																		
9.3	River Witham																		
9.4	River Stour																		
9.5	River Pant/Blackwater																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

support public water supply abstraction in the River Ancholme. These licensed abstractions are unlikely to be affected by the proposed abstraction.

Water Quality

The River Trent at Torksey is classified as NWC Class 2. The key water quality parameters are discussed further in Sections 5.9.2 and 5.9.3 below. It is considered unlikely that there would be major water quality impacts downstream of the Torksey intake, but detailed fieldwork and modelling is required. Dilution downstream, in the estuary and in the Humber estuary would be protected by a prescribed flow set on teh basis of downstream needs.

Fisheries

Due to tidal influences on depth velocity regime and the likely setting of a prescribed flow, impacts of the abstraction on fisheries are likely to be minimal.

Aquatic Ecology

The biological class at Winthorpe is classified as B with a BMWP score of 92 and ASPT of 4.20. This is considerably below that predicted by RIVPACS. Abstraction is unlikely to adversely affect the instream ecology.

Terrestrial Ecology

The effect of the proposals on the conservation value of the Trent and Humber Estuary is very difficult to assess and requires further research. Reduced freshwater inputs could have some impacts on the salinity regime. There are a small number of grasslands of county importance in the floodplain of the River Trent that are dependent upon infrequent, overbank flooding during winter. However, peak winter discharges are unlikely to be significantly affected by the abstraction.

Recreation/Navigation/Amenity

The River Trent downstream of the Torksey intake is used for both water sports and angling. It is unlikely that they would be significantly affected by the proposed transfer. The Trent is a statutory navigation waterway and this would be unaffected by the transfer, provided a suitable prescribed flow is set.

Summary

There do not appear to be any significant environmental risks associated with this component, subject to the prescribed flow being set at a sufficient level to meet downstream needs, including those of the Humber estuary and migratory salmonids.

5.9.2 Fossdyke Navigation from Torksey to River Witham

This is an artificial waterway controlled by British Waterways Board.

Hydrology

Under the proposed transfer option an additional 200 Ml/d would be pumped from the River Trent into the Fossdyke Navigation. This would result in total nett daily transfers of 420 Ml/d with peak flows due to pump restrictions at high tide and leakage of 571 Ml/d. This is estimated to increase velocities in the Fossdyke Canal by 0.3 m/s to 0.5 m/s at peak transfer rates. British Waterways Board suggest a maximum velocity in the Fossdyke Navigation of 0.5 m/s. Under present transfer rates the velocity is increased by 0.2 m/s. Therefore under the proposed scheme the increase would be 0.5 m/s to 0.7 m/s. In order to achieve this additional flow and ensure navigation velocity needs are met it has been estimated that the additional head required would be about 0.4m.

Water Resources

No impact is anticipated on existing abstractions.

Water Quality

The general water characteristics of the River Trent at Dunham (nearest sampling point just upstream of Torksey), the Fossdyke Navigation Canal at Saxilby, and the River Witham at Five Mile House are given in the report by WS Atkins (1992).

Overall the similarity between the water quality characteristics of the Trent and Witham is notable, with broadly similar mean and maximum values for most parameters. However, maximum ammonia concentrations in the Witham exceed the limits for public water supply abstraction; therefore increasing the existing transfer from the River Trent by up to 600 tcmd should have a positive diluting effect. Nitrate levels in both rivers are at or near the limits for public water supply abstraction. Conversely, orthophosphate concentrations within the Witham are, in general, below those in the Trent. However, it should be noted that for the period considered in the water quality study orthophosphate concentrations were higher in the Witham than the Trent. Occasionally high levels of sulphate in the Trent at Dunham should be further investigated.

Levels of conductivity and metals within the River Trent at Dunham are below the limits specified for irrigation and livestock watering in the draft water quality standards associated with recent NRA SWQO proposals, although average chloride concentrations are in excess of the lower limit for chloride sensitive crops. Conductivity, which provides a measure of total dissolved salts is higher in the River Witham than in the

Trent. Increased reliance on Trent supported water for irrigation or livestock watering should not therefore have significant adverse effects.

Fisheries

The Fossdyke canal is relatively uniform in section and is a popular match fishing venues for mixed coarse fish especially roach and bream. Transfer volumes along the Fossdyke canal will involve a depth increase of 0.4m and velocity increases from 0.2 to 0.5 m/s during peak periods. Although quite fast, the new velocity regime would not be unfavourable to species such as roach, and there might be increases in numbers of chub and dace at the expense of bream. However, chub and dace might not be favoured by the onset of a two stage flow regime, "no-flow" and "transfer" flow. The overall value of the fishery would not be significantly changed.

Aquatic Ecology

The impacts on the Fossdyke, an artificial waterway, especially in terms of flow velocity, would change the type of aquatic fauna, favouring high velocity preferring taxa at the expense of "backwater" taxa, to an extent dependent on the frequency of use of the scheme. The transfer is unlikely to result in overall degradation. Marginal macrophyte beds would be important for sustaining low-velocity habitats in this artificial channel.

Terrestrial Ecology

Increased flow velocities are unlikely to affect sites of conservation importance along the channel, however, any engineering works would need careful planning and consultation but might offer opportunity for enhancement.

Recreation/Navigation/Amenity

The Fossdyke Navigation was built by the Romans and is the oldest artificially constructed waterway in the county which is still navigable. It has statutory navigation rights, and this has important amenity value for boating and canoeing as well as for angling. Under operational conditions the impact on this watercourse is likely to be minor however, uncertainty exists over the effects increased velocities may have on angling and the potential for transfer of Zander. In addition, uncertainty exists over the amounts of construction works that might be necessary to allow for the increased flow. It is likely that the amount of construction, for example, alteration to bridges, relieving peak velocities at pinch points, bank raising, bank protection, channel lining and alterations to lock, would be relatively minor. However, care would have to be taken during construction works to maintain the character of canal, minimise any sediment input and minimise any disruption to navigation.

Summary

Although there are a number of uncertainties with this component, in particular the effects of increased velocities, the general indication is that the environmental risks associated with it can be considered low. Care would be needed in planning, design and construction of works.

5.9.3 River Witham

Hydrology

The Fossdyke Navigation joins the River Witham in Lincoln. There are no gauging stations along this reach of the River Witham although there is a gauging station at Claypole Mill about 35 km upstream. At this location the mean flow is 150 Ml/d and the Q_{95} low flow is 30 Ml/d. the minimum recorded monthly flow was 5 Ml/d in July 1976. The mean annual flood is 1547 Ml/d. The River Witham is tidal and the saline limit is at Boston.

From the above hydrological information the existing transfer of 240 Ml/d represents a significant change in the flow regime of the river. Even if the Q_{95} at Lincoln is double that at Claypole Mill the existing transfer represents 360% of the low flow in the river. If the transfer is increased by a further 200 Ml/d by this option this would represent 700% of the low flow in the river and 950% of the low flow at peak transfer rates. Atkins (1993) suggested that flows in the River Witham would be limited by the acceptable flow velocities for navigation, taken to be 0.7 m/s on average. The critical reach of the River Witham is the 'Glory Hole' at High Bridge where the channel narrows over a length of about 100m. This limits the maximum supported Witham flow through High Bridge to 750 Ml/d. This represents 20% of the design flood taken as 3715 Ml/d and means that even under average flow conditions maximum transfer quantities could not be routed through Lincoln via High Bridge. Atkins (1993) suggested that 400 Ml/d to 500 Ml/d could be transferred along Sincil Dyke, however, several hundred metres of channel would require improvement. This transfer would improve water quality in Sincil Dyke downstream of Lincoln by dilution of sewage effluent.

Although the flow change would be within the natural range of variation the transfer would change the seasonality of the river. Atkins (1993) suggested that no additional river improvements would be necessary and that the channel would be able to handle these flows. However, bank protection would be required for some sections of Sincil Dyke which already experiences erosion problems with current flood flows.

Water Resources

No impact on water resources are anticipated as a result of this transfer.

Water Quality

The impacts on water quality are the same as those discussed in 5.9.2 above. Atkins (1993) suggested that increased reliance on Trent water should not present problems in relation to potable water supply from the River Ancholme which is already supported by Trent transfers from the Witham.

Fisheries

The River Witham is an artificial channel with low gradients resulting in an essentially pooled and slow flowing fishery. Flows tend to vary according to rate of draw-off at Boston from virtual standstill to a few cm/sec. The river provides good angling for roach and bream.

The transfer would result in a 160% increase in mean flow which, due to the pooled nature of the river, would cause relatively small velocity changes in fisheries terms. Low flows would be significantly increased by a factor of eight.

Impacts are likely to be moderate with the habitat remaining essentially favourable to slow water coarse fish species flow. There are, however, uncertainties associated with changing the low regime which, although within the natural range of variation might have some adverse effects on angling.

Aquatic Ecology

The Witham is heavily channelised and already significantly affected by transfers from the Trent. Higher velocities are likely to be associated with the proposed increase in transfer. However, impacts would be mitigated by enlarging the channel cross profile. It is not considered that there will be major impacts upon the aquatic ecology.

Terrestrial Ecology

No adverse impacts on any sites of nature conservation are foreseen.

Recreation/Navigation/Amenity

The River Witham has considerable amenity value for boating. Under the proposed transfer scheme navigation would be unaffected provided velocities are kept below levels critical for boat traffic. Care would have to be taken during any construction works to minimise any sediment input to the river and not disrupt navigation. Particular care would have to be taken not to affect High Bridge, a listed medieval structure, for example, by diverting part of the transferred flows into Sincil Dyke. Uncertainties exist over the effects on angling particularly at low flows in the River Witham.

Summary

There are moderate risks associated with this option based largely on the uncertainties associated with changing the flow regime in the River Witham. Although flows would be within the natural range of variation there might be adverse impacts on angling. Operational measures to limit flow changes would serve to mitigate the impacts.

5.9.4 Pipeline Witham - Ely Ouse

The most direct route between the Witham at Boston and the Ely Ouse at Denver sluice has been assessed. It would require two major tunnel sections to cross the Welland and the Hundred Foot River. These rivers have high flood banks that enclose the river and associated washland that have been designated as SSSIs. The tunnel sections should minimise the environmental impact.

5.9.5 Ely Ouse-Essex Scheme

Hydrology

The initial part of the transfer within the Ely Ouse-Essex scheme is the cut-off channel from Denver Sluice to the Blackdyke Intake. The channel was constructed for the purposes of land drainage, flood alleviation and transfer of water to Essex rivers from the Ely Ouse. Under flood conditions it is used to take water from the rivers Wissey, Little Ouse and Lark and divert their flood waters away from Ely and Denver and transfer them directly to the Wash north of Kings Lynn. Under low flow conditions this channel forms part of the Ely Ouse-Essex transfer scheme where water flows in reverse direction down the cut-off channel from Denver Sluice to the Blackdyke intake. From this location water is transferred via a tunnel, Kennet pumping station and pipeline, to the upper reaches of the River Stour at Kirtling Green outfall. Further pipeline transfer occurs from Wixoe intake on the Stour to Great Sampford outfall on the River Pant.

There are no gauging stations on the cut-off channel, however, Atkins (1993) indicate that it would have no difficulty in handling the additional 200 Ml/d under the proposed transfer scheme. The channel is an artificial structure which already experiences a totally unnatural flow regime. It is possible that increased recharge would occur to the chalk aquifer around the cut-off channel.

Water Resources

No impact on water resources are anticipated as a result of this transfer.

Water Quality

No water quality data are available for the cut-off channel, however, there is no indication that the water quality in this channel would deteriorate from the transfers providing the intake from the pipeline discussed in 5.9.4 above runs directly into the cut-off channel. However, water from the Ely Ouse already included in the transfer route does present potential risk of high chloride levels (4000 mg/l and conductivity 9000 ms/cm) resulting from saline incursion through the gates of Denver sluice. In addition, chloride levels are already up to 1000 mg/l from time to time in the cut-off channel at Blackdyke Bridge. Anglian NRA report that engineering/management measures at Denver sluice have halted ingress of saline water.

Fishery/Recreation/Navigation/Amenity

Although a non-navigable waterway this channel has considerable local amenity value and is used for angling. Under the proposed scheme the transfer of additional water into this channel might have an effect on the of flow and depth changes, with subsequent effects on fisheries.

Summary

The environmental risks associated with this component are minimal.

5.9.6 River Stour

General Character

The Stour is of semi-natural character running through gently undulating chalk downland, primarily arable agriculture.

Hydrology

The hydrology of the catchment is heavily influenced by the existing Ely Ouse-Essex Transfers.

Mean flow at Kedington gauging station (catchment area 76 km^2), 7 km downstream of Great Bradley is 58 Ml/d and the Q_{95} low flow is 3.5 Ml/d. The minimum recorded monthly flow is 1.7 Ml/d in August 1976. Bankful discharge taken as Q_{10} is 147 Ml/d. The Stour at Lamarsh gauging station (catchment area 480.7 km^2) has a mean flow of 207 Ml/d, a Q_{95} of 52 Ml/d and a minimum monthly flow of 19.8 Ml/d in August 1976. Bankful discharge taken as Q_{10} is 406 Ml/d.

However, the river is already heavily regulated by the Ely Ouse-Essex scheme. The present capacity of the Ely Ouse-Essex scheme which discharges to the Stour is 334 Ml/d. These discharges dominate the hydrology of the catchment and have already led to a change in seasonality of flows. It would appear that the upper Stour must already be heavily channelled to carry the existing transfer flows.

Under the proposed transfer scheme a maximum additional flow of 200 Ml/d would be discharged into the upper Stour at Kirtling Green outfall. This represents a very substantial change in the natural flow regime in the upper Stour (110 x Q_{95}) which would require channel modifications to avoid the risk of significant erosion. There would be less of a change from the present regulation flows of the Ely Ouse-Essex transfer scheme.

Even downstream at Lamarsh, the additional flow of 200 Ml/d combined with the existing 334 Ml/d being transferred under the Ely Ouse-Essex scheme would be outside the natural range of variation of the river and the seasonality would be further altered.

Water Resources

There will be no adverse impact on the water resources of the River Stour downstream of Kirtling Green outfall.

Water Quality

The Stour water quality characteristics are influenced by high chloride and conductivity values of existing Ely Ouse transfers. In the vicinity of Wixoe the river is assigned NWC Class 2, RQO F2/LW/MA. Anglian NRA consider the observed high conductivity and chloride values in 1976 and 1991 to be due to leaking gates on the Ely Ouse, and that ingress can/has been controlled by engineering/management. Poor water quality is characterised by:

- conductivity and chloride levels frequently above values set for spray irrigation (in-catchment and transfers);

- maximum nitrogen values more than twice the acceptable for potable water supply abstraction (mainly derived from in-catchment sources).

Nitrates are particularly a problem during springtime, probably due to agricultural usage in the catchment although there is some loading from Ely Ouse transfers. There is also a risk of high chlorides depending on timing of transfers. Given the magnitude of low flows in the Stour, the water quality within the catchment would correspond to the Witham and Ely Ouse water.

There is unlikely to be an improvement in quality from the present Class 2 as River Witham water is also Class 2, although the Ely Ouse is Class 1B.

Aquatic Ecology

The river is already considerably augmented by the inter-basin transfers from the Ely Ouse-Essex transfer scheme. The river ecology is already highly artificial although further degradation is likely to occur. The impact on the aquatic ecology at the regional scale would be small.

Recreation/Navigation/Amenity

The upper reaches of the Stour have considerable amenity value although between Kirtling Green outfall and the Wixoe intake the river is not navigable.

There are numerous footpaths and bridal paths used by local people together with angling along this reach of the Stour. Indeed, there are plans to develop the amenity value of this reach of the river, possibly to include a canoe slalom at Kirtling Green outfall. Great care would be needed to minimise disruption and reduce the effects on water quality during any river improvement works which would certainly be required to increase the capacity of the channel. Uncertainty exists over the effects on water quality and angling by further disrupting the natural flow pattern in this river.

There have already been problems associated with the present Ely Ouse-Essex scheme namely:

- rapid changes in flow causing change in turbidity;
- rapid change in flow and depth, possibly affecting fish spawning between March and June;
- scouring and bank erosion;
- transfer of contaminants for pollution incidents;
- possible transfer of sugar beet rhizomania from beet factory effluents discharged to the Ely Ouse;
- possible transfer of Zander;
- local flooding problems;
- algal growth in recipient waters due to transfer of high nutrient rich waters;
- rapid drying up of upper reaches of the Stour when the pumps have been shut off.

Benefits of transfers include the control of blanket weed and possible dilution of chemical contamination, within the catchment.

It is likely that the problems detailed above would in general be exacerbated by further transfers of large volumes of water into the upper Stour. The possible exception is a slight improvement in water quality resulting from transfers from the River Witham, particularly reduction in nutrient levels and chloride and nitrate levels. The impact on amenity is variable. Benefits to water sports from increased flows must be offset against possible detrimental effects on fisheries and additional scour and bank erosion. The effects of this component would be very similar to those discussed for Great Bradley in Section 5.8.3 although slightly less extreme.

Summary

This river is already heavily regulated by transfers from the Ely Ouse, with transfers of over 100 x Q_{95}, which have led to a number of environmental problems. Additional transfers from the Trent are likely to increase the potential for problems, although some mitigation could be provided by suitable operating rules. There is particular uncertainty over water quality issues since the Trent water would be transferred via a number of rivers and the final quality is uncertain. Effects on ecology and fisheries are likely to be significant. Environmentally sensitive channel design and construction could improve habitats, landscape and amenity. There appears to be at least moderate environmental risks associated with this component of the Trent to Essex transfer option in comparison to the present regulation from the Ely Ouse. The river will be dramatically altered by comparison with the natural state.

The introduction of storage into the system, for example at Great Bradley, would allow mitigation of some aspects of the transfer.

5.9.7 River Pant/Blackwater

General Character

The River Pant has been heavily channelised and has a man-made character below the Great Sampford discharge point.

Hydrology

The hydrology of the River Pant/Blackwater is already regulated by existing Ely Ouse-Essex transfers, with releases taking place at Great Sampford. The mean flow at Capford Hall gauging station (catchment area 62.5 km^2) is 30 Ml/d, with a Q_{95} of 1.7 Ml/d, and maximum water flows of about 250 Ml/d. Further downstream at Stisted (catchment area 139.2 km^2) the River Blackwater statistics are mean flow 65 Ml/d, Q_{95} 13.8 Ml/d and minimum monthly flow 6.9 Ml/d. The proposed transfers would change the seasonality of flows.

Proposed maximum transfers of an additional 200 Ml/d appear in excess of the bankful capacity of the Pant/Blackwater at the points described above (using Q_{10} as bankful capacity 86 and 130 Ml/d respectively), and at Longford (catchment area 337 km² - Q_{10} 250 Ml/d). Further extensive channel changes would therefore be required throughout most of the river length to take the flows passing to the Essex reservoir intakes. The impacts of this transfer would be less dramatic than the maximum releases proposed for Great Bradley reservoir of 305 Ml/d (see Section 5.8.4) although clearly there would be significant impacts.

The River Pant downstream of Great Sampford has already been heavily channelised, and Atkins (1993) suggest that an environmentally sensitive approach to channel modifications could improve the character and general ecosystem value.

Water Resources

No impact on water resources is anticipated resulting from this component.

Water Quality

Like the Stour, the Pant/Blackwater water quality is already influenced by Ely Ouse transfers with elevated chloride values of up to 387 mg/l, although this quality may be improved by engineering/management of tidal gates on the Ely Ouse. Overall, water quality is assessed as NWC Class 1B/RQO F1/SI/LW/MA. Nitrogen levels are substantially lower than in the Stour.

Additional transfers from the Trent to the Pant/Blackwater via the Ely Ouse and Stour would be likely to raise nitrate levels, and perhaps chloride levels depending on the timing of transfers. No change is expected in un-ionised ammonia levels. The transfer discharge quality would dominate the system, with Ely Ouse water altered by any modification on blending of water from the Trent, Witham and Stour. There is potential to reduce the water quality of the Blackwater by transferring further lower quality Stour water into the upper reaches of this river system.

Fisheries

The River Pant/Blackwater is mainly a chub/dace fishery, with most reaches classified as Class A fisheries based on biomass and population density. However, reaches upstream of Bardfield Mill (which supports limited trout population) are only Class D, largely due to natural and possibly man-made flow changes. Coarse fisheries could be improved, in terms of water quality, by regulation from further transfers into this system although the water quality changes need further study.

As with the Stour, algal blooms could cause large scale fluctuations in diurnal oxygen, significantly raising BOD and cause clogging of gill structures of fish.

Aquatic Ecology

The BMWP scores for the River Pant range from moderate to good. The river has been heavily channelised and is likely to have been adversely effected by intermittent transfers from the Ely Ouse scheme which has resulted in scouring of bed material and vegetation. The potential for impacts upon channel stability and consequent aquatic ecology would increase with the proposed transfers.

Recreation/Navigation/Amenity

Impacts would be limited to effects on angling as described above. Landscape, general character and amenity could be significantly enhanced by adoption of an environmentally sensitive approach to channel modifications.

Summary

Despite the fact that this river is already greatly affected by the current Ely Ouse-Essex scheme there are uncertainties surrounding the transfer of such large volumes of water into the river via a number of river systems. Potential problems are similar to those presented in the summary for the River Pant with the introduction of Great Bradley reservoir (5.8.4 above). Particular uncertainty surrounds the effects on water quality after transfer through the rivers, and therefore the subsequent effects on fisheries and aquatic ecology. There appears to be at least moderate environmental risks associated with this component of the Trent to Essex transfer option, in comparison to the resent regulation from the Ely Ouse. By comparison with its natural state the river will be dramatically altered.

The introduction of storage into the system, for example the Great Bradley reservoir, would allow mitigation of some aspects of the transfer.

5.10 OPTION 10: Broad Oak Reservoir

General Description

The proposed Broad Oak reservoir scheme would involve the impoundment of the Sarre Penn valley north of Canterbury together with an intake/discharge pipeline from Plucks Gutter on the River Stour. This would enable water to be pumped into the reservoir from the Stour during high flow periods and then directly into public supply. It is also possible that compensation releases would be made back into the Stour during low flow periods for environmental reasons. The reservoir would be sited on agricultural land and some woodland. The details of this scheme are the subject of a confidential study by Binnie & Partners (1991) together with Oakwood Environmental carried out for three water companies. The engineering components of the scheme are as follows however, they are only in outline as detailed information is confidential:

- Dam impounding the Sarre Penn valley, the size is unclear but the top water level is likely to be between 41.5m AOD and 47.0m AOD.

- Intake at Plucks Gutter on the Stour.

- Pipeline from Plucks Gutter to Broad Oak reservoir.

- High lift pumping station to pump water along the pipeline from Plucks Gutter to Broad Oak.

The summary environmental assessment for this option is shown in Table 5.10, and the detailed assessments of components is given in Appendix D.

Assumptions:

For the purposes of this study the reservoir has been taken to be filled by inflow along Sarre Penn and pumped water from the River Stour at Plucks Gutter. No compensation releases would be made back into the Stour at Plucks Gutter. Broad Oak reservoir is taken to have a TWL of 41.5m AOD and a yield of 50 Ml/d.

5.10.1 Broad Oak Reservoir

There is currently no information on land use impacts associated with the construction of Broad Oak Reservoir apart from information outlined in 'Water for the Future in Kent, Issues and Options' 1991 by Binnie and Partners. It is understood that reservoir levels below 41.5 metres above O.D. would mainly impact improved farmland (largely grade 3) and very few buildings would be inundated.

5.10.2 River Stour, Downstream of Intake at Plucks Gutter

The River Stour at Plucks Gutter is subject to tidal influences. The river at this location is semi-natural.

Hydrology

No gauging stations exist on the reach of the Stour near to Plucks Gutter however, there is a gauging station at Horton upstream of Canterbury. At this site the catchment area is 345 km^2 and the mean flow is 278 Ml/d, the minimum monthly flow is 73 Ml/s recorded in September 1990 and the Q_{95} low flow is 97 Ml/d. The mean annual flood is 1840 Ml/d. The impact of the proposed scheme on the hydrology of the Stour downstream of Plucks Gutter cannot be fully assessed due to the fact that the report which contains this information is confidential. However, some details are in the public domain.

TABLE 5.10 Option 10 Environmental Assessment

OPTION 10. Broad Oak Reservoir
COMPENSATION: Unknown

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA	Ag	Com	Arch	GLC	TE	RA
10.1	Broad Oak Reservoir																		

COMPONENT		CONSTRUCTION RISKS						OPERATIONAL RISKS						BENEFIT OPPORTUNITIES					
		WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH	WQ	F	AE	TE	RAN	OTH
10.2	Sarre Penn d/s Reservoir																		
10.3	Great Stour estuary d/s Abstraction																		

RISK/OPPORTUNITY KEY:

HIGH
MODERATE
LOW
NOT APPLICABLE

CATEGORY KEY:

WQ = WATER QUALITY
F = FISHERIES
AE = AQUATIC ECOLOGY
TE = TERRESTRIAL ECOLOGY
RAN = RECREATION/AMENITY/NAVIGATION
OTH = OTHER GENERAL PLANNING ISSUES
Ag = AGRICULTURE
Com = COMMUNITY IMPACTS
Arch = ARCHAEOLOGY & CULTURAL HERITAGE
GLC = GENERAL LANDSCAPE CHARACTER

The prescribed flow in the Stour at Plucks Gutter is 145 Ml/d for the present minor abstraction.

Water Resources

The average yield of Broad Oak reservoir with a top water level of 41.5m AOD is 50 Ml/d. If the top water level of the reservoir was set at 47m AOD instead of 41.5m AOD and the minimum acceptable flow in the Stour at Plucks Gutter was set to 145 Ml/d, as it is at present, then the average yield would increase to 98 Ml/d. However, if the minimum acceptable flow at Plucks Gutter was to be reduced to 89 Ml/d then the yield of the reservoir would rise to 136 Ml/d. There is a possibility that a control structure downstream of Richborough power station could be considered at a later stage which would enable this reduction in the minimum acceptable flow to be made without detrimental effect on fisheries, recreation, and navigation.

There are two main abstraction requirements downstream of Plucks Gutter. One is water used for agricultural irrigation in the marshes around the Isle of Thanet. Maximum daily abstraction for this purpose is about 27 Ml/d, however this only includes pumped transfers and not gravity fed transfers. The second is the power station at Richborough, located 7km downstream of Plucks Gutter, which uses on average between 30 Ml/d and 50 Ml/d on a put and take basis for cooling purposes, however this can rise to 137 Ml/d for short periods. The timing of abstractions is dependent on tidal conditions.

Water Quality

The effects on water quality downstream of the intake at Plucks Gutter are likely to be complex due to the domination of tidal influences. There might be increased penetration of saline water into the estuary which could have a significant effect on the marshland around the Stour estuary, however this can be limited by the setting of suitable operating rules for the scheme. . The flow in the Stour downstream of Plucks Gutter is also used to dilute sewage effluent from Minster Sewage works and Plucks Gutter treatment works. The degree to which this dilution is reduced as well as dilution of pollution from urban runoff will have to be considered when setting a minimum acceptable flow.

Reduced flood flows downstream could result in a change in siltation rates in the estuary downstream and change in flooding patterns.

The tidal reach of the Great Stour/Stour from Grove Ferry, just upstream of Plucks Gutter, to the sea is classified as A under the estuarine water quality scale. If the reservoir were to be used for compensation releases to the Stour then care would have to be taken to prevent algal blooms in the river. There is strong potential for the development of eutrophic conditions in the reservoir.

Fisheries

The river is tidal up to Fordwich, north east of Canterbury, and about 10 km inland of the proposed abstraction point at Plucks Gutter. There will therefore be no effect on fisheries in the non-tidal reaches and the upper 10 km of the tidal zone.

The Stour is largely a coarse fishery, but some reaches have been culled and stocked with trout. There is a run of migratory fish, which is small compared to the more northern rivers, but significant in the region, however there is little quantitative data for the salmonoid fishery. The fishery is boosted with hatched fry. Salmonids consist of brown trout, sea trout and salmon. Although the upper reaches should have good populations of brown trout, surveys found only low populations (due possibly to the impact of M20 construction). Heavy siltation has also been exacerbated by recent drought.

The estuary and lower reaches have good coarse fisheries. Downstream of Plucks Gutter species composition comprised rudd, stickleback, bream, flounder, mullet, sea trout, dace, eel, gudgeon, perch, roach and stoan loach. The survey undertaken by WS Atkins (1990) revealed that approximately 47% of population was roach, followed by bream at 22.6%. At Plucks Gutter, total biomass $10.7 g/m^2$, Roach 35% biomass (47% of community), bream 36% biomass (23% of community) gudgeon 0.5% biomass (3% of community) and dace 1% biomass (4% of community).

There would be negligible effect on fisheries in the upper/middle reaches of the river, and little effect on the tidal reaches from the scheme as long as low flows are protected by suitable operating rules including prescribed flow/ compensation flow.

Aquatic Ecology

The Great Stour has an interesting morphology, its setting with its valley gives high aesthetic values, and it contains a rich and diverse fauna and flora. The proposed scheme would not affect the non-tidal river and the 10 km of tidal river above Plucks Gutter.

The invertebrate community of the non-tidal Great Stour is generally rich and diverse throughout. Mayflies are well represented with over ten species recorded, as are caddis flies. The upper reaches are predictably the most diverse with BMWP scores ranging from 167 at Rippers Cross (Biological band A) and ASPT of 5.1. to 137 downstream at Vauxhall (Canterbury). Downstream of Canterbury the river becomes slow flowing and alluvial in nature. The invertebrates show corresponding changes with species present that are typical of sedimentary conditions. The numbers of mayfly and caddis decrease until brackish species increase from Minster Marshes. BMWP scores decrease to 93 at Grove Ferry and 107 at Plucks Gutter. The number of families reduce to 21 at

Grove Ferry to 25 at Plucks Gutter, with corresponding ASPTs of 4.4 and 4.3. The RIVPACS predicted BMWP and ASPT scores are in excess of existing scores at 172 and 5.2. The biological banding is classified as B.

Aquatic vegetation below Plucks Gutter, downstream of the abstraction point and in the tidal zone, comprises very limited marginal aquatic flora which is unlikely to be affected by the abstraction given suitable operating rules.

Terrestrial Ecology

There are a number of sites of nature conservation interest in the lower Great Stour corridor. In addition parts of the Great Stour itself have been designated of county nature conservation importance.

The majority of the sites however are located upstream of Plucks Gutter and should be unaffected by abstraction. Sites downstream of Plucks Gutter include Ash Level and South Richborough Pasture which is a Grade 1 site of nature conservation importance (SNCI). The site comprises low-lying agricultural land with inter-connecting dyke systems between the River Stour and Goshall Stream. Some unimproved pasture and rough grassland still remains.

Ash Levels and South Richborough Pasture receive water from the Great Stour via the Providence and Grip sluices and also through flooding of grazing land adjacent to the river. This provides valuable habitat for birds such as garganey, shoveler, teal, lapwing, snipe and meadow pipits. These areas are unlikely to be affected by upstream abstraction. However, possible increases in salinity and reduced availability of irrigation water need further research.

Sandwich Bay and Hackling Marches SSSI, a proposed SPA/Ramsar site, is located at the mouth of the river. The site includes the best sand dune system with coastal grassland in south-east England, and also includes mudflat, saltmarsh, freshwater marsh, scrub and woodland. Further work on the extent and effects of saline intrusion on existing erosion and sedimentation balance may need to be carried out. Some fields in the saltmarsh adjacent to the Stour flood at high tide, so any reduction in frequency or extent of flooding could affect the ecology here.

Without specific details on the location of the reservoir it is not possible to assess impacts on Sarre Penn. It should be noted however that Chislet Marshes and Sarre Penn is a Grade 1 SNCI. The SNCI is restricted mainly to the dykes and river only. Some unimproved pasture remains near Marshide Village.

Recreation/Navigation/Amenity

The Great Stour valley has considerable recreational and amenity value. The Great Stour is tidal up to Fordwich, just north east of Canterbury, and is therefore a navigable waterway. However, the low bridge at Grove Ferry just upstream of Plucks Gutter prevents the passage of large boats but small cruisers can pass through with many mooring at Fordwich. There are numerous watersports being undertaken along the Stour and waterskiing and windsurfing in the estuary. There is considerable angling interest and numerous footpaths focused on the river itself. Birdwatching is popular in the Stour valley and estuary.

The most likely potential impact on amenity of the Stour resulting from the Broad Oak reservoir would be on angling through reduced water quality, although the effects need further investigation. There is also a potential impact on commercial navigation, particularly at low flows, which also needs further investigations. There is also uncertainty over public health effects resulting from reduced dilution of sewage effluent in the river and estuary.

Summary

There appear to be low to moderate potential environmental risks associated with this component and these can be met by the setting of a suitable prescribed flow or compensation flow in the Stour and the Sarre Penn.

5.10.3 Sarre Penn, Downstream of Reservoir

The proposed Broad Oak reservoir would impound the Sarre Penn valley.

Hydrology

There is a gauging station on the Sarre Penn at Calcott upstream of the tidal reach, with a catchment area of 19.4 Km^2. The mean flow is 8 Ml/d and the Q_{95} low flow is classified as less than 0.5 Ml/d. The minimum monthly flow is also classified as less than 0.5 Ml/d in September 1990.

The hydrological effect of the reservoir depends largely on whether or not compensation releases are made to attempt to maintain a 'natural' flow regime downstream. If this is not the case then the Sarre Penn stream would almost certainly dry up for all but wettest periods. The river is subject to tidal influences in the lower reaches.

Water Resources

There are no known abstractions from the Sarre Penn although it is possible that abstractions do occur for spray irrigation. This needs further investigation.

Water Quality

Water quality sampling on the Sarre Penn is undertaken on a regular basis by the NRA only at Chislet Park, and occasionally elsewhere. This stream appears to be fairly nutrient rich with high nitrates, but relatively low phosphate concentrations. The chloride levels can show continuous fluctuations in the lower reaches due to influxes of saline water from the Great Stour at Plucks Gutter. However, the levels at Chislet Park are consistently low.

There are considerable environmental impacts on water quality associated with the construction of Broad Oak. Water quality in what remains of the Sarre Penn after construction is complete is almost certain to be reduced, however if compensation releases are made then the water quality could be improved. Care would need to be taken to prevent algal blooms being transferred into the Sarre Penn if compensation releases are made. During construction there is a possibility of increased sediment discharge being released into the Sarre Penn and the Stour downstream of Plucks Gutter. This could be ameliorated by careful planning.

The loss of periodic flooding could result in increased penetration of saline waters.

Terrestrial Ecology

Sarre Penn is a site of county nature conservation value. Impacts on the SNCI need further research.

Recreation/Navigation/Amenity

There is considerable uncertainty regarding the amenity impacts of this scheme although during the construction phase there is likely to be an impact. However, the long term impacts depend on whether compensation releases are made. There is scope for improvement of amenity value of this reach, particularly angling. This is not a navigable waterway and therefore no impacts on rights of navigation or water sports are anticipated. The visual impact resulting from the river drying up could be considerable however compensation releases could improve conditions.

Summary

There appear to be very limited environmental risks associated with this component subject to suitable operating rules to protect low flows. There is real potential for environmental benefits and the possibility of improvement through careful planning.

The details for a full assessment of the impact of this scheme are the subject of a confidential report by three water companies. Unless this is made available or further work is undertaken the full impacts cannot be realistically assessed.

5.11 Other Options

A preliminary assessment of all possible ways of meeting future resource deficits was included in the reports by Halcrow (1991, 1993). These options were eliminated from detailed consideration either because of excessive cost, or as being environmentally unacceptable or due to a lack of firm proposals. However, several effluent reuse schemes were included in the resource optimisation studies and selected as components of least cost scenarios (e.g., re-use of Deephams WWTW effluent in London). A brief commentary on the environmental implications of each option is included below.

5.11.1 Surface Water Schemes

Effluent Reuse

In Britain, used water is returned either to rivers from sewage treatment works or is discharged to sea with only limited treatment. Indirect reuse, where sewage effluent is returned to a river and subsequently abstracted downstream, is widely practised. Most major abstractions for public water supply, such as those for the main London reservoirs, are situated close to the tidal limit, and consequently take full advantage of this resource. The EC Urban Waste Water Directive will require effluents discharged to the sea to be treated by 1998 or 2000, according to the sensitivity of the receiving waters. It is possible that this will involve pumping the sewage to existing or new inland treatment works, thus increasing the resource availability in the receiving watercourse.

Large volumes of treated effluent are discharged to the tidal reaches of Britain's major rivers, and are thus effectively lost to the freshwater system. For example, some 2400 Ml of treated effluent is discharged to the Thames estuary each day, a volume which is equivalent to almost 40% of the total daily abstraction of groundwater in England and Wales. Potentially, much of the demand increase in the London area over the next 20 years could be met by diverting a proportion of this effluent at times of low flow into the non-tidal river system, immediately downstream of the lowest point of abstraction. Subject to the required level of treatment the effluent would augment the residual flow in the Thames, and thus enable an equivalent amount of the natural flow upstream to be abstracted without derogation of the statutory minimum requirements for the estuary. The diverted effluent would require treatment to a high standard in order to avoid the deterioration of water quality in the estuary.

Alternatively, the treated effluent, after disinfection, could be diverted directly to storage reservoirs for mixing with raw water before further treatment and distribution. Although treatment technology is now sufficiently elaborate to reduce health risks to a minimum, one of the more difficult questions in assessing the potential for the direct reuse of effluents is the public perception of a scheme that deliberately increases the treated sewage element of supplies for domestic consumption. Similar social considerations apply to the dual potable and non-potable supply systems found in some towns overseas, and in a number of industrial areas in the UK.

Key environmental issues are:

- The technology exists to treat effluent to a suitable standard for direct reuse, including potable supply. It is more efficient to run effluent reuse programmes in conjunction with industrial pre-treatment, which limits the trade discharge of complex organics and metals, although advanced treatment of the effluent can remove such contaminants. The storage of treated water in reservoirs or rivers allows further self-purification. Effluent reuse is increasing worldwide, although the water is often used for irrigation or aquifer recharge.

- Major pollution problems may arise from system failures.

- Additional treatment facilities could have landscape and visual impacts, but these can only be assessed for specific proposals, and can generally be mitigated by sensitive design.

Estuary Barrages

The WRB study in the 1970s saw estuary barrages on the Dee, Wash and Morecambe Bay as potential schemes for future resource development. They expressed concern about the environmental acceptability of effectively damming estuaries, which have been borne out by the experiences of estuary barrages in Holland. Abstraction at the lowest point in the non-saline river is clearly environmentally optimal for the upstream catchment, but the construction of barriers at this location has severe implications for sensitive estuary environments.

Key environmental issues are:

- A full tidal barrage eliminates saline intrusion, fundamentally altering the water quality characteristics of the estuary. A second problem with all tidal barrage schemes is the diffusion into the stored freshwater of salt trapped in the bed of the reservoir, although this may be overcome with suitable management. Estuary barrages are positioned at the mouth of the river, at a point where the feeder river water quality is generally low due to upstream discharges. Adequate dilution must be allowed for existing discharges to the tidal waters.

- Construction of a barrage would cause considerable resuspension of sediments, significantly affecting the downstream water quality; a major concern would be absorbed contaminants, likely to be in high concentrations at lower depths. The release of anaerobic muds and organic materials suitable for microbial metabolism is likely to result in significant, albeit local, oxygen depletion.

- The Wash is an extremely important nature conservation site, being designated a SSSI, a RAMSAR site and a Special Protection Area. Reservoir construction on the foreshore, altered sedimentation, abstraction and laying of pipelines would affect nature conservation and cultural artefacts.

- Morecambe Bay is also designated as a RAMSAR site, a Special Protection Area and an Area of Outstanding Natural Beauty. A full barrage would affect sedimentation and salinity pattern, much of the sand and sandflats would be inundated, having a significant impact on the ecology of the Bay.

- Potential deterioration of salmon runs.

- Agricultural improvements due to improved drainage.

5.11.2 Groundwater Schemes

Direct Abstraction

It is generally acknowledged within the NRA that the potential for further conventional development of groundwater in England and Wales is very limited. Proposals for further abstraction in certain areas, including groundwater schemes in Hampshire and the Vale of York, are now being re-evaluated in recognition of their potential impact on river flows and local or regional groundwater levels. In Dorset, consideration is being given to relocating points of abstraction towards the coastline, in order to relieve the impact of existing schemes in the upper catchments. The cumulative impacts of reduced low flows within catchments underlain by the main aquifers in central and southern England have resulted in revision of resource estimates and sustainable development levels.

Key impacts are:

- Lowering groundwater levels around the boreholes can adversely affect wetland sites, agriculture, and trees which depend upon a high water table.

- Groundwater abstraction may reduce and even dry up spring flows throughout the catchment, with damaging consequences for high quality headwater streams.

- The systematic reduction in baseflow may reduce effluent dilution resulting in a long term deterioration in water quality, or problems with effluent treatment and disposal.

Groundwater Augmentation Schemes

Groundwater augmentation schemes for river regulation to support downstream abstraction are already widespread in England. There are existing plans to extend the Shropshire Groundwater Scheme for regulating the Severn. This has been included in the resource model optimisation studies. There is also a long standing proposal to augment the Ouse from the Vale of York aquifer in order to support increased abstraction to the Yorkshire Grid. The environmental impacts of several existing UK schemes are described in Appendix C.

In addition to those mentioned above for groundwater abstraction, key environmental issues are:

- A change to the temperature regime of the receiving waters, particularly of smaller watercourses, including a depression of summer temperatures, is usually predicted.

- Borehole water is generally low in dissolved oxygen, although oxygen levels will rapidly equilibrate during or after release. Groundwater is usually slightly supersaturated in dissolved nitrogen.

- Augmentation can result in significant changes to baseflow chemistry due to differences in ammonia, orthophosphate, alkalinity, chloride, calcium and nitrate.

- Groundwater tends to be rich in dissolved minerals and can contain high nitrates if beneath areas with intensive agriculture.

- There are environmental benefits from augmentation if the receiving watercourses are already suffering from low flows, either flow quantity or inadequate effluent dilution. However, since the cause of excessive low flows is usually groundwater over development, the long term benefits of augmentation need to be carefully assessed.

Artificial Recharge

Experiments with artificial recharge of groundwater have been carried out since the late 1950's (Boniface, 1959) and a number of such schemes are now being implemented. Notable amongst these is the

Enfield-Haringey scheme in the Lee Valley, currently under development by Thames Water. The scheme is based on the injection under low pressure of off-peak treated mains water into the Chalk aquifer, to supplement natural recharge, and subsequent use of the storage as required. Schemes involving the recharge of treated sewage effluent are also under consideration. The principal objective of artificial recharge, however, is to meet short-term peak demands and supply shortfalls during periods of drought, rather than to augment the total value of the groundwater resource.

The environmental benefits of artificial recharge arise from the potential to raise groundwater levels and to dispose of effluents with only limited treatment. Nevertheless, the quality of the recharge water requires careful control to avoid clogging of the pores in the aquifer close to the injection wells. It may therefore be necessary to store and treat water prior to recharge, involving facilities potentially giving rise to noise, odour and visual intrusion impacts unless carefully designed. Although there is little information on the effects of dispersing water of different chemical composition throughout aquifers, this may result in adverse changes to the water quality. Such changes have been observed in the Lee Valley pilot schemes, where fluctuating water levels induced by recharge and abstraction have led to the dissolution and re-precipitation of sulphate minerals in the Basal Sands.

Key environmental issues are:

- Water quality of the recharge water needs to be carefully controlled, for example, with respect to pH, redox potential and suspended solids concentrations. Experience at a number of locations, for example, Birmingham Racecourse and Sherwood Sandstone, have encountered problems with small quantities of suspended sediments in the recharge water causing clogging close to the borehole well.

- Dispersion of water of differing chemical composition may result in adverse changes, most significantly the dissolution and reprecipitation of sulphate containing minerals. Dissolution and reprecipitation of minerals may also result from alternating wetting and drying at the aquifer margins. Experience at two sites in the Lee valley, using the Chalk and Lower London Tertiary aquifer, has shown that poor groundwater quality has been exacerbated by artificial recharge, due to the oxidation of sulphides on dewatering of the aquifer during periods of over-abstraction. At most other sites groundwater recharge has had little effect on groundwater quality.

- There is little information on the environmental implications of artificial recharge although in general they appear limited.

- Pipeline and lagoon storage and borehole construction may have adverse visual impacts/land use implications, but these can usually be mitigated by careful design.

Use of Rising Groundwater Beneath Cities

There are proposals to increase abstraction for public water supply from aquifers beneath London and Birmingham. Declining direct abstraction over the past century combined with increased total leakage losses (a combination of density of supply and increased mains pressure), has led to rising groundwater beneath Birmingham and London. Increased abstraction for public water supply is being investigated both to halt the rise, thus protecting basements, services and the London Underground, whilst at the same time providing new resources.

Key environmental issues are:

- There are unlikely to be any adverse consequences on the natural environment, resulting directly from the abstraction, other than the potential derogation of nearby smaller wells.

- There are considerable potential benefits to halting the continued rise of groundwater levels which may eventually cause damage to foundations, services, and underground tunnels, such as the London Underground. CIRIA have estimated potential economic benefits of over £150M for the London Basin.

- There are risks of pumping water of a quality unsuitable for public supply without blending or treatment. In central London the groundwater can be relatively saline, while in Birmingham there is a risk of drawing in pollutants from contaminated land.

5.11.3 Alternative Transfer Options

National Water Grid

A national water grid was first considered in the 1940's. Broadly this would comprise a network of pipelines and aqueducts connecting three areas with surplus resources - the Kielder reservoir, the enlarged Craig Goch reservoir scheme in mid-Wales, and sources in the north-west region - with regions of potential shortfall. Re-examination of the scheme by the NRA has indicated that it would not be viable on the grounds of high capital costs and energy requirements. The environmental impacts of a direct abstraction piped network would be both adverse, in that the transfer system would involve a net loss from the supply sources with no beneficial river regulation component, and potentially beneficial in eliminating the need to change the flow regime in recipient river systems with potential effects on water quality, ecology, fisheries and other receptors.

Key environmental issues are:

- The transport of water in a series of pipelines from storage bodies (reservoir or aquifer) to the demand centres would obviate concerns about biological transfer to the recipient waters, as the raw water is expected to need some conditioning prior to transfer to minimise biological growth in the pipeline. In addition to biocide treatment, continuous flow of water in the grid would eliminate problems associated with stationary water becoming anaerobic or stagnant.

- Pipeline construction would result in temporary, and perhaps some permanent impacts, on sites of nature conservation interest, protected species, landscape and archaeological sites.

- No instream impact from river regulation for transfers, other than indirectly through changes to large scale regulation by reservoirs and direct abstraction.

Undersea Pipelines

The possibility of transferring water by undersea pipeline from Kielder, from Ireland or from France has been the subject of a number of prefeasibility studies. These options are relatively expensive but they are relatively quick to build, are not subject to the same planning restrictions as on-land pipelines, and are likely to have fewer environmental implications than major river regulation and transfer options.

Key environmental issues are:

- The raw water is expected to need some conditioning prior to transfer to minimise biological growth in the pipeline. In addition to biocide treatment, continuous flow of water in the grid would eliminate problems associated with stationary water becoming anaerobic or stagnant.

- Construction of undersea pipelines could cause considerable resuspension of sediments, significantly affecting the local water quality; a major concern would be absorbed contaminants, likely to be in high concentrations at lower depths along the near shore. The release of anaerobic muds and organic materials suitable for microbial metabolism is likely to result in significant, albeit temporary and local, oxygen depletion.

- Possible destruction of marine plant and animal communities during construction, but along a very narrow route.

- Temporary affects on organisms arising from localised deterioration in water quality.

- Possible affects on shellfish and crustacean fisheries during pipeline constructions and fin fish spawning and nursery areas.

- Disturbance to local fin fish migration pathways.

- Possible adverse affects on sites of nature conservation interest if pipeline crosses an estuary.

Tankers/Water Sacs/Icebergs

These rather esoteric options were discussed in the Halcrows (1993/ report on Other Options). Whilst there may be particular local circumstances where they are viable, they could not provide the scale of resources of concern here.

Key environmental issues are:

- The raw water is expected to need some conditioning prior to transfer to minimise biological growth in the hold/sac. The water would need treatment on arrival, with particular attention paid to treatment of odour and taste.

- There is little information on the environmental implications of water transfer in tankers/water sacs, although in general they appear limited.

5.11.4 Desalination

Enhancing supplies by desalination of sea or brackish estuarine waters (WRB, 1972) involves high economic and environmental costs. Desalination processes, whether by distillation or reverse osmosis, have substantial land and energy requirements, and involve the disposal of concentrated brine effluents.

Key environmental issues which can generally be avoided or mitigated by careful design and construction are:

- The technology exists to treat seawater to a suitable standard for direct reuse, including potable supply. Indeed, desalinisation projects exist worldwide, including within the UK, providing water for both industrial and potable uses. Recent projects are reducing in cost, such that this option may become more economic over the coming decade.

- Desalinisation effluent is highly saline, up to 50 or more parts per thousand salinity, leading to hypersaline conditions in the discharge area. The hypersaline water, being more dense, sinks to form a highly saline benthic layer. Reactions with increased salinity include increased pH to the point when calcium carbonate is precipitated, with an attendant drop in alkalinity, and an increase in the specific heat of the seawater resulting in greater diurnal temperature fluctuation.

- Metal concentrations are similarly concentrated in the effluent. During normal operations, copper is released, although higher concentrations of metals, including copper, nickel and iron, are released during cleaning. Metal toxicity is dependant upon factors such as pH, presence of suspended particles and the chemical form of the metal. Chemicals used in the desalinisation process, such as defoaming agents, are either toxic or coat surfaces.

- Distillation desalinisation processes can increase ambient seawater temperature by up to 15°C, causing reductions in the seawater oxygen content. Furthermore, increase in salinity will cause the specific heat of the water to reduce causing greater fluctuations in diurnal temperatures and a reduction in dissolved gases held in solution.

- The discharge of hypersaline, heated water will have both a localised direct effect on marine life, and could alter the marine community in an extended area.

- Elevated levels of available metals could give rise to bioaccumulation and biomagnification.

- Dense, hypersaline water will have a detrimental impact on benthic organisms.

- Fish will be able to avoid saline areas unless the saline plume blocks a migration route, or covers a nursery/pairing ground.

- Widespread growth of filamentous algae and a reduction in invertebrate diversity.

- During 'cleaning' operations, the copper concentrations increase by 5-10 times background concentrations. This harms some species but benefits others thereby altering the invertebrate community. In Jersey no invertebrates were found in the effluent stream.

6. COMPARISON OF OPTIONS AND KEY ISSUES

6.1 Alternative Strategies

Under present forecasts, a pattern of marginal deficits between available resources and demands may develop around the country over the coming 30 years, which may necessitate either the development of new regional resources or inter-region transfers or both. Many of the options described in Chapter 5 are complementary, but some are direct alternatives. The transfer alternatives for meeting regional deficits are discussed in sections 6.2 to 6.4.

Alternative strategies to meet the deficit can be considered as a hierarchy of choices with increasing environmental risks for a given scale of project. However, there may be site specific reasons which completely change these rankings, such as the inundation of a SSSI, and there may be circumstances in which one major scheme is preferable to the accumulated effects of several small schemes. The hierarchy is:

- Demand reduction/control of losses
- Local resource developments:
  - Effluent reuse schemes
  - New reservoirs
  - Groundwater
- Inter-regional transfers:
  - Pipeline transfers
  - Canal transfers
  - River transfers
  - Undersea pipelines
  - National water grid
- Unconventional options:
  - Desalination
  - Estuary barrages
  - Tankers/water sacs

Ideally, there should be some limit to the growth in demand. The goal of sustainability means that the level of resource exploitation should be set with reference to available resources, having due regard for environmental needs. The present commercial and regulatory position in the UK makes this a difficult area, but as guardians of the environment the NRA has questioned ever rising demand forecasts. Significant demand reduction is possible through a combination of tight leakage control targets, metering, public education and demand suppression at times of shortage. Active demand management policies may be politically undesirable, but on environmental grounds it is far better to reduce demand than to develop new resources. The Countryside Commission and English Nature (1993) consider demand management measures to be essential components of sustainable development, whilst the Council for the Protection of Rural England (1991) sees a strong parallel between the need to reassess the use of water in the UK and the debate in the energy sector over greater efficiency.

Although OFWAT has a long term commitment to payment by quantity, they proposed that household metering should only be introduced where it could be demonstrated to be marginally cheaper than new resource development (OFWAT, 1993). To make this a fair comparison, it is essential that the environmental impact of developing new resources is included in the equation, and economic techniques for this purpose need to be developed. The installation and operation of a metering system involves high costs, which may exceed the benefit to many consumers, and has social implications for equity and the availability of water at an affordable cost to the public.

Leakage and 'unaccounted for water' amounts on average to around 25% of the water supplied, and setting targets for its reduction could consequently have a very significant effect on future water requirements. Although the water companies have achieved considerable savings in recent years, the cost-effectiveness of leakage control becomes questionable at some level. The optimum sustainable level will vary between regions, according to the nature and age of the existing system. In Germany, rates as low as 3% have been reported (Butler and West, 1987), but the capital investment programmes required to achieve these levels have led to exceptionally high unit costs of water. The DoE has noted that there is scope for introducing environmental costs, such as those arising from the impact of increased abstraction on wetlands, into the economic evaluation of optimum leakage levels (DoE, 1992).

Where there is still potential for developing new local resources, either by effluent reuse (such as Deephams), new groundwater schemes (such as the extension of the Shropshire Groundwater Scheme), or new reservoirs (such as Broad Oak), and providing the schemes can be developed whilst incorporating environmental objectives, then they have inherently less risks than large-scale interbasin transfers unless transfers are made directly into supply. Such options can be and are being addressed at the regional level.

The less conventional options, such as desalination or estuary barrages, have considerable environmental risks and usually very high costs. But it is important to bear in mind that in particular circumstances (such as on the Channel Islands), such alternatives may be viable.

The main options for meeting regional deficits in Thames, Trent and Anglian regions are discussed below. The advantages and disadvantages of each option are summarised in Table 6.1, and Figure 6.1.

TABLE 6.1 KEY ADVANTAGES AND DISADVANTAGES OF STRATEGIC OPTIONS

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 1: Severn - Thames Transfer Transfer of 400 Ml/d to Thames at Buscot from Unsupported Severn	Does not involve significant engineering works Benefits through renovating the Thames - Severn Canal Increased flows may prove beneficial in supporting low flows to upper Thames and possible reduction in frequency of channel maintenance Given existence of good quality tributaries, impacts on aquatic ecology may be short lived (or might recover from downstream drift) No adverse effects on recreation	Upper Thames might become more than 80% lower Severn water during low flow periods with significant changes to biochemistry impacts on water quality and transfer of disease, parasites, bioaccumulation Impact on the aquatic ecology of donor and recipient rivers Effects of transferring up to 4 times dry weather flow could impact on morphology, habitat, washout or fish fry and macroinvertebrates	The key issues relate to establishing water quality and biological impacts Extending the pipeline to discharge into South West Oxfordshire reservoir for blending would make this scheme more acceptable. It is important to ensure that downstream SSSIs near Deerhurst are not adversely affected and that there are sufficient residual flows to allow for salmonid migration up the Severn Fisheries interests would be a key issue Might need to consider operation in conjunction with Farmoor reservoir (without South West Oxfordshire reservoir)
Option 2: Enlarge Craig Goch Reservoir Transfer to Thames at Buscot from the Severn Regulated by an enlarged Craig Goch	Severn already regulated and instream impacts unlikely to be significant, although care should be taken to ensure some marginal seasonal-dry, gravel-cobble habitats are exposed Moderate recreation benefits from construction of reservoir No long term adverse water quality implications foreseen No impacts on reach downstream of Deerhurst since abstracted quantity would be balanced by reservoir releases	Significant adverse effects on sites of nature conservation arising from enlargement of Craig Goch, including partial loss of internationally important SSSI at Elenydd Significant local effects on the extent of inundation of salmonid nursery areas in late summer will need further research Frequency and duration of high flows over the summer months would be severe	Adverse effects on sites of nature conservancy value are likely to be significant issues affecting acceptability

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 3: Enlarged Craig Goch Transfer to Thames at Buscot from the Wye Regulated by an Enlarged Craig Goch	Major changes likely to be confined to a short reach downstream of the Ithon confluence Moderation of extreme flow ranges may provide benefits in improved habitat stability Regulation of the Wye is dependent on water releases from the upper catchment (Craig Goch) which is unlikely to adversely affect water quality within the Wye	The natural condition of this river is rare in the UK, it is an SSSI Peak regulation releases of 400 Ml/d into the Wye at Nannerth will significantly impact on the flow regime (habitats and ecology) of a 6 km reach of the river Principal concerns relate to the extent that the altered flow regime will affect salmonid spawning reaches Transfer of Wye derived water from Deerhurst to Buscot could have adverse impacts Low level of similarity between instream fauna of the River Wye at Ross-on-Wye and the River Thames at Buscot	There are a number of uncertainties relating to environmental and water quality implications of this transfer. In general this scheme appears to have adverse nature conservation implications due to the enlargement of Craig Goch and regulation effects on the River Wye Impacts for channel morphology and channel bed stability/sedimentation have not been assessed
Option 4: Redeployed Vyrnwy Reservoir Redeployment of Vyrnwy to Regulate the Severn	No significant infrastructure associated with redeployment Use of multiple draw-offs to mitigate temperature and water quality problems likely to mitigate impacts on aquatic ecology	Major impacts on low-flow regime for more than 30 km Vyrnwy is an important salmonid river and reservoir releases will affect main spawning and juvenile reach. Maintenance of stable nursery areas without excessive washout will need further consideration	Downstream implications for wetland habitats require further research

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 5: South West Oxfordshire Reservoir Construction of New Reservoir at Abingdon to Regulate the Thames	No scheduled ancient monuments affected No landscape/planning designations affected Impacts on agriculture are considered moderate/low Significant recreational resource coupled with nature conservation benefits Possible benefits to Wiltshire-Berkshire canal	Considerable local construction impacts for many years Visual impacts significant Effects on land drainage would need mitigation Would require effective control and management of abstraction, discharge and stored water to minimise potential effects on water resources and water quality Possible algal development Post construction recreation and transport pressure	Considerable construction impacts, significant visual impact Downstream implications for wetland habitats require further research
Option 6: Canal Transfer Transfer to the Thames at Oxford from the Regulated Severn via BWB canals of 100 Ml/d	Water quality improvements in certain stretches of canal Long term amenity and recreational benefits Increase in flow velocities to 0.5 m/s could enhance coarse fisheries due to increased DO and less siltation	Water quality problems associated with discharge of eutrophic and polluted water to the Thames Possible adverse effects on instream ecology and fisheries associated with dredging Increase in flow velocities may impact on navigation Visual and amenity disturbance associated with construction works along 200 km of canals Some stretches include SSSIs and other restrictive planning designations Possible further spread of fish species	The water and environmental quality implications for the Thames would require considerable further investigations

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 7: Severn to Trent Transfer Severn to Trent Transfer via Penk and Sow of 100 ml/d	Effects on abstractors negligible No adverse effects on water quality on the Severn Possible water quality benefits for the River Penk, the River Sow and the River Trent Impacts upon low flows within the Upper Trent is likely to be beneficial, maintaining a diversity of habitats during drought years	High local impacts on aquatic ecology in the Penk and Sow (although it should be noted that the biological quality is moderate to low) Possible transfer of fish disease (Pomphoryncus) to the Trent. Disease is not thought to have caused fish mortalities elsewhere.	Site specific planning constraints along pipeline route need more detailed research and sufficient flows in the Severn are needed to allow for upstream migration of salmonids
Option 8: East Anglian Reservoir Great Bradley Reservoir and Existing Ely Ouse-Essex Scheme Note: These comments apply only to a new reservoir at Great Bradley. At least one other potential site is available, yet to be studies in the same detail, for which the impacts will be different	Construction of a reservoir at Great Bradley would provide significant long term nature conservation and recreational opportunities Potential improvements might accrue in the quality of water transferred from the existing Ely Ouse scheme to the Rivers Stour and Pant by the introduction of interim storage within Great Bradley. The reservoir would also enable improvements to be made in the timing and rate of releases An environmentally sensitive approach to channel modifications in the Rivers Stour and Pant could redress some of the adverse effects of historical regulation works on aquatic ecology	Four ancient woodland SSSIs and a further five ancient woodlands would be affected by reservoir construction Loss of residential properties due to reservoir construction; a significantly smaller number of properties and area of woodland would be affected if a small reservoir is constructed Possible adverse effects on siltation, water quality, fisheries and ecology of the tidal Ely Ouse and the Wash Estuary SSSI/Ramsar Site due to reduction in flows in tide Increased flow releases to the Rivers Stour and Pant are likely to affect instream ecology Increased transfers are likely to affect water quality characteristics of the River Pant	As with all reservoirs, it is likely to be subject to considerable local opposition. If a small reservoir is constructed the advantages are similar but the disadvantages are considerably reduced Impacts on regulated rivers could be ameliorated by sympathetic operation (timing and rate)

Option Description	Advantages	Disadvantages	Environmental Acceptability
Option 9: Trent to Anglian Transfer Unsupported Trent to Essex Transfer of up to 200 ml/d	No major water quality impacts downstream of Torksey No adverse effects on recreation in the Trent No significant adverse effects on water quality in the Witham Fisheries impacts arising from abstraction will be minimal Increase in velocity in Fossdyke unlikely to affect value of fishery No major impacts on the aquatic ecology of the Witham	Reduced freshwater inputs to the Humber Estuary needs further research Impact of reduced flows on siltation/ navigation needs further research Change in aquatic fauna in the Fossdyke is likely to occur. Marginal macrophyte beds are essential to sustain low-velocity habitats in this channel Potential water quality problems (eg organophosphates and sulphates) in the Trent being transferred to the Witham and Essex rivers Possible adverse effects on angling in the Witham Impact of 57Kms pipeline/tunnel during construction	This scheme is acceptable provided concerns about transferring lower quality Trent water into the Ely Ouse-Essex scheme can be overcome through further studies, and if necessary, treatment of contaminants such as phosphates and sulphates Impacts on regulated rivers could be ameliorated by sympathetic operation (timing and rate)
Option 10: Broad Oak Reservoir	It is understood that the reservoir mainly occupies improved farmland (Grade 3) and few buildings would be inundated Given appropriate operational rules to ensure normal recovery in the autumn, the scheme need not impact upon the instream aquatic ecology	Possible changes in water quality as a result of reduced dilution of sewage effluent and urban run-off and possible changes to saline and silt regime in the estuary Sarre Penn is a SNCI	This option is acceptable provided appropriate operating rules are included to control abstractions from the Stour and releases to Sarre Penn Need to ensure periodic flooding for downstream wetland sites

Figure 6.1

COMPARATIVE ENVIRONMENTAL APPRAISAL OF STRATEGIC OPTIONS SUMMARY MATRIX

DEMAND CENTRE	OPTIONS/COMPONENTS	SENSITIVITY								POTENTIAL ENVIRONMENTAL RISKS																BENEFIT OPPORTUNITIES							
										CONSTRUCTION								OPERATION															
		Fisheries	Terrestrial	Water	Recreation	Agriculture	Community	Archaeology	Landscape	Fisheries	Terrestrial	Water	Recreation	Agriculture	Community	Archaeology	Landscape	Fisheries	Terrestrial	Water	Recreation	Agriculture	Community	Archaeology	Landscape	Fisheries	Terrestrial	Water	Recreation	Agriculture	Community	Archaeology	Landscape
THAMES	WYE/SEVERN - THAMES TRANSFER																																
	Core Components:																																
	Pipeline Deerhurst-Down Ampney Gravel Pits	•	•	•	•	•	•	•	•	•/	●/	•/	•/	●	•	•/	●/	/	/	/	/	/	/	/	/								
	Restored Thames & Severn Canal	·	·	·	·					·	·	·	·					•	·	·	·					•	•		●				
	River Thames Buscot-Eghom	●	●	●	●					·	·	/	·					•	·	●	·					·			•				
	Variable Components:																																
	Unsupported-Severn d/s of Deerhurst	●	●	●	●					•/	·	•/	·					•/	·	•/	·												
	Enlarged Craig Goch Reservoir		●		•	·	·	•	•		●		•	·	·	•	•		●		·	/	/	•/	•		·		•	·	·	·	·
	Regulated Severn to Deerhurst	●	·	●	•					•/	·	•/	·					•/	·	•/	·					•	·	•	·				
	Regulated Upper Wye to Ross	●	●	●	•					•	•	•	·					●	•	•	·					·	·	·	·				
	Pipeline Ross-Deerhurst	•	•	•	•	•	•	•	•	•/	●/	•/	•/	●/	•/	•/	●/	/	/	/	/	/	/	/	/								
	River Vyrnwy regulated by redeployed Vyrnwy Reservoir	●	·	●	·					·	·	·	·					●/	·	·	·					·	·	·	·				
	Regulated Severn to Deerhurst	●	·	●	•					•/	·	•/	·					●/	·	•/	·					•		•					
	ABINGDON RESERVOIR																																
	Abingdon Reservoir		·		·	•	●	•	·		·		·	•	●	•	•		·		·	·	•	·	•/		●		●		·	·	·
	River Thames Culham-Egham	●	●	●	●					•/	/	•	·					●/	/	●/	·					•	·	•	•				
	BWB CANAL TRANSFER																																
	Pipeline Coalport-River Penk	•	•	•	•	•	•	•	•	•/	•/	•/	•/	•/	•/	•/	•/	/	/	/	/	/	/	/	/								
	River Penk to River Sow Confluence	•	·	•	·					·	·	·	·					•	·	·	·					•	·	●	·				
	River Sow to Heywood Jct.	•	·	•	·					·	·	·	·					·	·	·	·					•	·	●	•				
	BWB Canals:Heywood Jct.-Isis Lock	•	•	•	●					●	•	•	•/					•	•	·	·					•	·	●	•				
	River Thames d/s of Oxford Canal	●	●	●	●					●	·	●	·					●	·	●	·					·	·	·	·				
EAST MIDLANDS	SEVERN TRENT TRANSFER																																
	Pipeline Coalport-River Penk	•	•	•	•	•	•	•	•	•/	•/	•/	•/	•/	•/	•/	•/	/	/	/	/	/	/	/	/								
	River Penk to River Sow Confluence	•	·	•	·					·	·	·	·					•	·	·	·					•	·	●	·				
	River Sow to River Trent	•	·	•	·					·	·	·	·					·	·	·	·					•	·	●	•				
	River Trent d/s of Great Heywood	•	•	•	•					·	·	·	·					·	·	·	·					•	•	•	•				
ANGLIAN	GREAT BRADLEY RESERVOIR																																
	Great Bradley Reservoir		●		•	●	●	●	•		•		·	•	●	/	•		•		•	•	•/	•/	•/		•		●			·	•
	Tidal Ely Ouse/Wash	●	●	●	●													●	·	·	●/												
	River Stour	•	•	·	●					•	•	·	o					•	·	•	•					•	•	•	•				
	River Pont/Blackwater	●	·	•	●					•	•	·	o					●	·	•	•					•	•	•	•				
	UNSUPPORTED TRENT TO ESSEX TRANSFER																																
	Trent d/s of Torksey	·	·	•	●					·	·	·	·					/	/	•/	•/												
	River Witham	•	·	•	●					·	·	·	·					•	·	•	•/					·	·	·	·				
	Pipeline Witham to Ely Ouse	•	•	•	•	•	•	•	•	•/	•/	•/	/	•/	•/	/	/	/	/	/	/	/	/	/	/								
	River Stour	•	•	·	●					•	•	·	•					•	·	•	•					•	•	·	•				
	River Pont/Blackwater	●	·	•	•					•	•	·	•					•	·	•	•					•	•	·	•				
SOUTHERN	BROAD OAK RESERVOIR																																
	Broad Oak Reservoir		•		·	•	●	●	•		•		•	•	•	•	•		•		•	•	•	•	•		·		•	·	·	·	·
	Sarre Penn d/s of Reservoir	·	·	·	·					•	·	•	•					•	•	•	•					·	·	•	·				
	Great Stour estuary d/s of Plucks Gutter	•	·	●	·					•	·	•	·					·	·	·	·												

CATEGORY KEY:

- Fisheries — FISHERIES AND AQUATIC ECOLOGY
- Terrestrial — TERRESTRIAL ECOLOGY
- Water — WATER QUALITY
- Recreation — RECREATION/AMENITY/NAVIGATION
- Agriculture — AGRICULTURE
- Community — COMMUNITY IMPACTS
- Archaeology — ARCHAEOLOGY AND CULTURAL HERITAGE
- Landscape — GENERAL LANDSCAPE CHARACTER AND OTHER GENERAL PLANNING ISSUES

LEGEND:

● ● ● HIGH

• • • MEDIUM

· · · LOW

/ / / INDICATES IMPACT CAN BE MITIGATED

NOTE: Blank spaces indicate that the category is not applicable

This matrix differs from that published in Water: Nature's Precious Resource, which was subject to amendment by NRA regions.

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6.2 Thames Region

The main strategic options that have been considered in this study for meeting deficits in Thames Region are:

Transfers from the Severn:

- Option 1: Transfer of up to 400 Mld/d to Thames at Buscot from the unregulated Severn;
- Option 2: Transfer of up to 400 Ml/d to Thames at Buscot from the Severn regulated by Craig Goch;
- Option 3: Transfer of up to 400 Ml/d to Thames at Buscot from the Severn regulated by Vyrnwy;
- Option 4: Transfer of up to 400 Ml/d to Thames at Buscot from the Wye regulated by Craig Goch;
- Option 6: Transfer of up to 100 Ml/d to Thames at Oxford from a regulated Severn via British Waterways Board (BWB) canals;

In-catchment Development:

- Option 5: Construction of a new pumped storage reservoir in South West Oxfordshire drawing on the Thames at Culham; regulation of Thames below Culham for abstraction to lower Thames reservoirs.

These options are not mutually exclusive as Severn transfers could be used to fill the South West Oxfordshire reservoir. In terms of speed of development, the unsupported Severn transfer to Buscot and the BWB canal transfer to Oxford could be implemented in a relatively short time, although both of these options give rise to serious environmental concerns and require further study. The construction of a new reservoir in South West Oxfordshire or the enlargement of Craig Goch would take a number of years to promote, gain planning approval and construct even if there were no environmental objections. Redeploying Vyrnwy could be implemented within a much shorter timescale, provided suitable replacement sources for North West Region are available.

The preliminary NRA figure for a prescribed flow constraint in the Severn at Deerhurst of 2500 Ml/d is about 1.5 times Q_{95}, which is in agreement with some salmon migration studies but is less than the 50% of mean flow suggested by other researchers. Provided the PF is set at a suitable value, no adverse impacts are expected in the Severn downstream. Considerable detailed studies and investigations are required to determine a suitable PF for the lower Severn and the estuary to be used as the basis for resource development.

The canal transfer option has a risk of impact through increased velocities within the canals which are themselves valuable aquatic habitats. The temporary disturbance caused by construction and improvement works along about 200 km of canals would be substantial. Set against this are potential water quality improvements to several poor quality canal reaches. There are high risks of impact on the Thames at Oxford, where significant discharges would be coming from a long canal network of generally lower quality than the Thames at the discharge point. Of particular concern are dissolved and particulate metals derived from canal bed sediments.

The Severn transfer into the Thames at Buscot carries high risks to the biochemistry of the upper Thames, which would become more than 80% lower Severn water during low flow periods. The riparian zone of the upper Thames catchment is now an Environmentally Sensitive Area. The Thames downstream of Buscot is already a highly artificial channel which is depth regulated for navigation, and there is concern that velocities may approach the limit for boat traffic. There are significant coarse fishery interests. On the plus side, there are considerable potential benefits by renovating the Thames & Severn Canal and supporting low flows to the upper Thames. Extending the pipeline to discharge either into a South West Oxfordshire reservoir for blending or direct to the Culham reach of the Thames, where dilution would be almost 1:1 at low flows, would both be far more acceptable.

Regulation of the Severn would provide a large, continuous resource for transfers to Thames and/or Trent Regions. The two potential sources considered are an enlarged Craig Goch reservoir or a redeployed Vyrnwy reservoir. Enlarging Craig Goch would risk serious damage to the internationally important SSSI at Elenydd and destroy two other SSSIs, and further studies are required to examine possible mitigation measures. The Craig Goch scheme is likely to meet with major opposition from a conservation perspective. Redeploying Vyrnwy would have a major impact on the downstream river receiving the reservoir releases which is the main spawning and juvenile reach for up to 40% of the salmon redds in the upper Severn. The risks to the Severn itself are also serious, although the river is already regulated. There are also knock-on effects of resource development in North West Region which have not yet been assessed. With different discharge arrangements, the Vyrnwy regulation could be more acceptable.

Regulating the Wye for transfer to Thames is likely to prove environmentally unacceptable. The Wye is a unique aquatic environment in Britain, an SSSI of international importance, and the best salmon river in England and Wales. One aspect of its uniqueness is its naturalness. It would have to be conclusively demonstrated that no element of that environment would be adversely affected by the revised flow regime, which would require years of baseline studies and would probably always be opposed by conservation groups. Added to which, the enlargement of Craig Goch would probably affect the high flow regime (of which no studies have yet been made), which could affect salmon migration. There appears to be little to recommend this option on environmental grounds.

The South West Oxfordshire reservoir offers the potential for considerable long term benefits, but its construction would have major short term local impacts. The scheme would develop new local resources, and obviate the need for transfers from outside the catchment with their inherent risks to the biological integrity of the Thames. The scheme would provide additional regulation and low flow support to the Thames. The reservoir itself could be planned to include a diversity of habitats and offer a valuable local amenity. The negative aspects of this scheme are all related to the major disturbance during the construction phase which is certain to generate widespread local opposition. Sensitive reservoir design, minimising impact on the landscape, would be an important factor in determining the environmental acceptability of the scheme. Of the options for meeting deficits within Thames Region, the reservoir seems to offer most long term benefits and least risks to the aquatic environment. Care would need to be taken with respect to temperature and quality of released water, and operating rules for abstraction and discharge to minimise velocity changes. The NRA would need to consider the extent to which the resources available in the Thames should be developed and the flow regime altered.

6.3 Severn-Trent Region

The only strategic option identified by the NRA for meeting regional deficits in Severn-Trent region is Option 7, to transfer up to 100 Ml/d to the Trent from the Severn via pipeline and the rivers Penk and Sow to supply the East Midlands. Other sources to meet increases in regional demands are the existing surplus in Carsington reservoir and future phases of the Shropshire Groundwater Scheme, the environmental impacts of which are not covered by this report.

The Severn-Trent transfer option would be relatively quick to construct and no major environmental impacts are foreseen. The transfer of higher quality Severn water into the upper Trent catchment is not the same issue as for Severn-Thames transfers, because the Trent is a lower quality river. Thus there are potential quality improvements to the Penk, the Sow and locally within the Trent. There may also be opportunities to improve the coarse fishery in the Sow through better quality and more reliable low flows. The only concern with this option is the impact on the Penk, whose low flow regime would be increased to a level where there might be long term bed and bank erosion problems and macrophyte washout, although the Penk has been the subject of recent channel changes which may mitigate this risk. The marginal cost-benefit of extending the transfer pipeline to discharge directly into the Sow should be investigated.

6.4 Anglian Region

Two strategic options have been identified for meeting marginal deficits in Anglian Region:

- Option 8: Great Bradley Reservoir with Ely Ouse-Essex scheme;
- Option 9: Unsupported Trent to Essex transfer.

Both schemes are an extension to the existing Ely Ouse-Essex transfer scheme. For the unsupported Trent option the major planning hurdle is the Witham to Denver pipeline, and there are risks to water quality. With both options there are important environmental issues to be addressed relating to water quality and the magnitude of changes to existing flow regimes particularly in the Essex rivers.

The Great Bradley reservoir, at the highest top water level of 105.5m AOD, would have a substantial environmental impact because of the destruction of 4 SSSIs, ancient woodland, listed buildings and the short and long term disruption to the Upper Stour Valley. The smaller reservoir at 99m AOD top water level would have significantly less environmental impact.

There is already a transfer between the Trent and the Witham using the Fosdyke Canal to supply Ancholme. Engineering works are required on the Fosdyke Canal if velocities are not to exceed navigation limits. The magnitude of the increased transfer gives rise to some concern for the capacity and quality of the Witham, but this is a highly artificial embanked channel with already regulated flows. Treatment would be required for specific pollutants in the Trent which are considered unacceptable (such as organophosphates).

Great Bradley reservoir at the highest top water level would cause the loss of 4 SSSIs, all ancient woodlands which are rare in the region, 5 listed buildings and 17 sites of archaeological interest. The disturbance during the construction phase would be severe and it is certain that there would be a well organised opposition campaign. Whilst there may be recreational benefits associated with the reservoir in the longer term, these appeare to be outweighed by the unmitigable environmental damage. However, the proportional impacts of a much lower reservoir of 99 m AOD compared to the assessed proposal of 105.5 m AOD are significantly less and it is possible that this variant may be acceptable. The need for additional storage in Anglian region is becoming apparent, and other options, such as a Fenland reservoir, require urgent investigation.

Both schemes involve common elements, particularly the increases to the only regulated flow regimes of the rivers Stour and Pant/Blackwater. These impacts are difficult to assess in the absence of detailed operating rules for the Essex rivers, but it is clear that the magnitude of change will be significant for the upstream reaches, and dramatic in terms of their natural flow regime. The length of reach affected is unknown, but would give rise to serious concern if the flow regime of the lower Stour in the "Constable Country" ancient landscape downstream were significantly altered. The key issue for both options is the acceptability of increasing the magnitude (doubling the flow in the case of the upper Stour) and duration of transfers using water from the lower Ely/Ouse, and further detailed studies and investigations are required.

Although both the Stour and the Pant/Blackwater are of biological class A, they have highly engineered channels, and are already heavily regulated. Thus the incremental impacts are not as severe as would be the case if these were natural streams. Nonetheless, the desirability of the NRA supporting the extension of the transfer scheme must be questioned. The lack of rigorous studies of the impacts of the existing transfer scheme is disappointing, but there is a lot of anecdotal evidence that the present scheme is far from beneficial for the aquatic environment. Mitigation could include managing the rivers to achieve defined environmental objectives, or making the transfer to the main supply reservoirs by pipeline rather than river.

The provisional minimum residual flow in the Trent of 2500 Ml/d should be sufficient to maintain the navigable channel and not cause temperature problems to downstream power stations, but on environmental grounds it appears low in comparison to western rivers such as the Severn. The latest research on migratory salmonids supports a MRF at the estuary of between 1 to 2 times Q_{95}, which would suggest a MRF of up to 5000 Ml/d. Detailed studies and investigations are required to determine a MRF for the Trent to be used as the basis for all resource developments in the catchment.

Increased high flow abstraction from the Ely Ouse at the Denver sluices, is a good option for increasing resources provided the minimum residual flow and high flows to the estuary are set to avoid siltation problems in the navigable channel and to sustain ecological needs within the Wash. These concerns are the subject of on-going studies by Anglian NRA.

6.5 Southern Region

The only strategic option for Southern Region selected by the NRA for assessment in this study was Broad Oak reservoir. Unfortunately, the lack of information about the reservoir in the public domain has limited the assessment.

The limited information available suggests that the scheme is environmentally acceptable. The abstraction point would be below the tidal limit and only average grade agricultural land would be inundated. However, it is stressed that no reservoir outlines and operating rules are yet available. The downstream impacts on the Sarre Penn, Pluck's Gutter and Great Stour depend entirely upon the operating rules for the abstraction and reservoir releases. Present proposals are that the PF will be set with reference to the existing Q_{95} plus supported abstractions, which will protect downstream abstractors and maintain a suitable MF to the Stour estuary. The main environmental concern is for the marshland SSSI at the estuary. A detailed study of the impact of any changes to the high and low flow regimes on this site would be needed.

6.6 Discussion

From a purely environmental perspective, the best option for meeting water resources needs up to 2021 is to reduce leakage and introduce demand management measures, such that as few new schemes as necessary are needed.

From the assessment of scheme specific risks and opportunities in Chapters 5 and 6, a number of general issues emerge. These issues hinge on the NRA's role as an environmental protection agency rather than an active promoter of schemes. The NRA's mission to both manage resources efficiently and to protect and enhance the environment does not make it clear how conflicts between efficiency (ie least cost) and uncosted environmental damage will be resolved. If a policy of "no deterioration" is seriously propounded, then virtually none of the options described in this report could be supported by the NRA.

The fact is inescapable, that all reservoir construction and inter-basin transfers will have some impact on the aquatic environment. The central questions here relate to the scale of change, ie local versus regional, and the significance of change, ie the degree of naturalness. Is it acceptable to the NRA to in effect sacrifice a small number of abundant first order streams in order to protect many others and regulate the Thames and Trent and to further regulate the Severn as well as other minor rivers? Is it acceptable to the NRA to inundate an SSSI? These are all issues which require urgent review before a national water resources strategy is produced.

A poignant question for the NRA to ask itself, as with the study of low flows due to groundwater over-abstraction, is: *Would large-scale inter-basin transfer schemes, such as the Ely Ouse-Essex scheme, have been granted licenses with the benefit of hindsight as to the effect on the receiving watercourses?* The absence of comprehensive studies on the impact of existing large scale transfer schemes makes it difficult to justify the extension of inter-basin transfers on an even grander scale.

Perhaps the most important lesson to be learnt from the evaluation of existing schemes, such as the Dee (see Appendix C), is that there appears to be no inherent reason why water resources schemes cannot be built and operated without causing severe long term environmental deterioration. Indeed, new schemes could offer long term benefits, provided clear environmental objectives are incorporated at the outset encompassing hydrology, water quality, ecology and fisheries together with river user requirements.

Small scale impacts associated with the construction of pipelines, pumping stations and small storage reservoirs can generally be overcome by careful design and route selection. The acceptability of these components is largely a matter for local planning authorities.

7. FURTHER STUDY REQUIREMENTS

7.1 Strategic Studies

Strategic study requirements identified in this report are:

- A Strategic Environmental Assessment of national water resources development options, focusing on NRA policies, rather than an assessment of selected options. The study would concentrate on strategic issues such as the acceptability of using natural watercourses as large scale transfer conduits as opposed to transferring directly into supply. The objective would be to set a policy framework which would encourage water companies or other developers to promote water resources schemes which were environmentally sustainable.

- A major investigation of the environmental impacts of existing UK transfer and regulation schemes, such as Kielder, Ely Ouse-Essex, Craig Goch, Vyrnwy, Clywedog and Roadford to establish the actual positive and negative environmental impacts of such schemes in UK conditions.

- An evaluation of economic techniques for quantifying environmental damage in the context of water resources projects. The objective would be to recommend simple techniques for providing environmental cost data for DoE and Ofwat marginal cost-benefit techniques.

- Minimum residual flow requirements to estuaries and in major rivers. There is still controversy concerning environmentally acceptable minimum flows at different times of the year, particularly migratory salmonid requirements. It must be clear whether naturalised or historic flow statistics should be used as a reference. The objective would be to produce national guidelines for all estuaries and major rivers.

- Continued research into the links between terrestrial wetland sites and hydrological regimes. The objective would be to set guidelines for acceptable changes to minimum water flows/levels and frequency of flooding for different categories of site.

- Fish disease transfer policy clarification. Recent test cases are questioning current NRA policy on fish diseases which, even when they occur, are not causing significant population damage. The objective would be to review existing policy and its impacts for strategic transfer options.

7.2 Option Specific Studies

Further study requirements specific to the strategic options considered in this report are:

- A reappraisal of the MRFs for the Severn and Trent in the light of recent salmon migration studies;
- Updated baseline surveys of the Vyrnwy, Tanat, upper Severn, upper Thames and to define their morphology, instream ecology and fisheries status would be essential before any option involving increased regulation could be considered;
- A detailed water quality investigation of the changes to base chemistry of the Thames at Buscot receiving a 400 Ml/d transfer from the lower Severn;
- A detailed water quality investigation of specific pollutant risks to the Witham receiving an additional 200 Ml/d transfer from the Trent;
- Detailed water quality investigations of the changes to base chemistry of the Pant/Blackwater and Stour receiving additional Ely Ouse-Essex transfers whether via Great Bradley or supported by Trent transfers.
- An independent assessment of existing environmental studies for Abingdon and Broad Oak reservoirs when these become available from the Water Companies;
- Catchment simulation studies for the Severn, Thames, Trent and Anglian Ouse to investigate the cumulative impacts on the flow regime of different combinations of schemes included in future development scenarios;
- Additional fisheries surveys of the Penk and Sow would be beneficial.
- A detailed investigation of the long term changes in river morphology likely to arise as a result of the strategic options, abstraction and regulation.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Review of Literature and Existing UK Schemes

The key findings from the review of the literature and existing UK schemes (see Chapter 3) are:

- There are no generally accepted methods of determining environmentally acceptable flow regimes, although current research is starting to define minimum acceptable flows using habitat simulation models with salmonid fish as indicator species;

- Aquatic ecosystems respond in synergistic, complex ways to changes in the flow and quality regimes, which in any case have a high natural variability; the primary criteria for defining the acceptability of change is that flow regimes remain within the historic range of variation, that natural seasonality is preserved, and that the timing and magnitude of spates are adequate for migratory salmonids;

- There is no consistent approach to setting minimum residual flows (MRF) applied in the UK. There is still controversy concerning the "hands off" MRF to estuaries to protect salmonid migration. Some researchers claim that 50% of mean annual flow is required, whilst others propose that 1 to 2 times Q_{95} is adequate;

- There are inherent risks in transferring large quantities of water into adjacent catchments, which relate to biological integrity, transfer of pathogens and diseases, predatory species, and "fingerprinting" confusion for migratory salmonids. Particular risks are associated with transfers from the downstream end of large lowland rivers into the upstream end of upland or middle order reaches, due to the disruption of the nutrient cycle.

- The presence of existing low flow rate connections between catchments through the canal network, negates some of the arguments concerning biological integrity.

- There has been a marked increase in the last decade in theoretical literature concerned with the ecological effects of river regulation, but there have been few studies of the specific effects of catchment transfers, and no environmental audits of transfer schemes have been carried out in the UK

8.2 Development of Environmental Assessment Methodology

A method for preliminary environmental assessment of the strategic options identified by the NRA appropriate to a strategic level has been developed based on a literature review, a review of the impacts of existing UK schemes, workshop sessions with NRA specialists and the expertise of those working on the project. The key features of the assessment framework (see Chapter 4) are:

- Each component (eg regulated river/canal reach or new reservoir/pipeline) of an option is assessed separately;

- The sensitivity, risk of adverse impact and benefit opportunities are assessed on a 3 point scale (low-moderate-high) for each component using explicit guideline criteria;

- Options have been compared by considering the advantages and disadvantages of each component and also by indicating the environmental acceptability of an overall option from the NRA's perspective as an agency with statutory environmental protection responsibilities. An option is considered difficult to accept if it has a high risk of causing unmitigable loss/damage to highly sensitive fisheries, or aquatic/terrestrial conservation sites.

8.3 Results of Environmental Assessment

Preliminary conclusions from the assessment at this strategic level (see Chapters 5 and 6) are:

- The most environmentally sustainable and acceptable strategy is to manage demand such that as few schemes as possible are required within the planning horizon.

- Option 1 to transfer up to 400 Ml/d to the Thames at Buscot from the unsupported Severn might be acceptable. Serious consideration should be given to extending the pipeline to discharge to the Thames at Culham or into the proposed South West Oxfordshire reservoir. There are potential conservation and recreation benefits from renovating the Thames & Severn Canal. A detailed assessment of the likely chemical, biological and velocity changes at Buscot and downstream reaches of the Thames is essential as are studies required to determine a prescribed flow to protect the lower Severn and estuary;

- Option 2 to regulate the Severn using an enlarged Craig Goch is difficult to accept because of the potential risk to an internationally important SSSI, loss of 2 other SSSIs, and potential impacts on the high flow regime of the Wye. Further studies of the option are required to establish the scale of the impact and the scope for mitigation, impacts on hydrology, river bed and ecology/fisheries in the upper Severn river need to be examined in detail.

- Option 3 to regulate the Wye using an enlarged Craig Goch appears to be environmentally unacceptable and should be eliminated from further consideration because of the likely impacts on a unique natural character river which is the best salmon river in England and Wales.

- Option 4 to regulate the Severn using a redeployed Vyrnwy reservoir may be environmentally acceptable but it would probably impact on salmon redds' spawning grounds in upper Severn tributaries, although this could perhaps be mitigated by new discharge arrangements. Knock-on effects of further developments in North West Region need to be investigated, as do the impacts on hydrology, river bed and ecology/fisheries in the Vyrnwy, Tanat and upper Severn;

- Option 5 to construct an embanked reservoir in South West Oxfordshire appears to be an environmentally acceptable scheme, provided the short term construction impacts are deemed acceptable by the planning authorities, the impact on landscape can be mitigated, and subject to detailed assessment of effects on ecology/fisheries from which to determine suitable operating rules and prescribed flow;

- Option 6 to transfer up to 100 Ml/d from the Severn to the Thames via the BWB canal system requires a large amount of construction works along 200km of canals, and is probably unacceptable because of the risk to the water quality of the Thames.

- Option 7 to transfer up to 100 Ml/d to the upper Trent from the Severn appears to be environmentally acceptable. The scheme would have less impact if the transfer was made direct to the Sow rather than via the Penk, because the proposed transfer flow could lead to macrophyte wash out and channel scour, although the Penk has been subject to recent channel improvement. There are potential water quality benefits to the Penk, the Sow and the Trent.

- Option 8 to construct a reservoir at Great Bradley needs to be carefully reviewed. At the proposed top water level of 105.5m AOD the scheme would mean the loss of ancient woodland SSSIs and housing and would be difficult to accept. A lower water level (99m AOD) would have significantly less effect. Alternative sites for a storage reservoir along potential transfer routes should be investigated. The effects of changes to the flow regime of the tidal Ouse downstream of Denver on siltation and ecology of the Wash require further study to determine a suitable prescribed flow as to the marked changes likely in the Stour and Pant/Blackwaters.

- Option 9 to transfer up to 200 Ml/d from the unsupported Trent to the Ely Ouse-Essex scheme via the Witham represents an increased rate for an existing transfer scheme. A prescribed flow for the Trent would need to be set, allowing for restoration of migratory fisheries if this is a long term objective for the river. Further studies of the water quality implications of the increased transfer and channel enlargement works on the Stour and Pant/ Blackwater watercourses are required.

- Option 10 to construct a reservoir at Broad Oak appears environmentally acceptable on the basis of the limited information made available for this study. The impacts on Sarre Penn and the Great Stour could be minimised by adopting appropriate control rules, and by appropriate setting of a prescribed flow.

- There may be other variants of the assessed options, eg longer pipelines or lower reservoir top water levels, which have significantly less impacts or important benefits.

- Alternative options such as desalination or undersea pipelines all have environmental advantages and disadvantages and may have a part to play in exceptional circumstances.

8.4 Requirements for Further Studies

Option specific studies might be best carried out by those promoting the scheme, although some fisheries, water quality and prescribed flow studies fall within the NRA's remit. The NRA would need to ensure that adequate option specific baseline data exists for determination of licence applications. Additional recommended studies (see Chapter 7) are:

- A strategic environmental assessment of NRA policies affecting the national water resources strategy;

- A review of economic techniques for costing environmental damage related to water resources projects;

- A comprehensive ex-post evaluation of the impacts of existing transfer and reservoir regulation schemes;

- The production of national guidelines for minimum residual flow requirements to estuaries.

- A review of fish disease transfer policy.

- Option 1 specific study requirements are:

    - Reassessment of the PF in the Severn to meet migratory fish needs;

- A detailed study of the likely water chemistry changes in the Thames at Buscot;

- An assessment of the fisheries impacts of changes to base chemistry at Buscot.

- Option 4 specific study requirements are:

  - An investigation of alternative discharge locations for Vyrnwy releases;

  - Inclusion of knock-on environmental effects in North West Region caused by Vyrnwy redeployment.

- Option 6 specific study requirements are:

  - Detailed assessment of water quality implications for the Thames of canal transfers.

- Option 7 specific study requirements are:

  - A fisheries survey of the Penk and Sow.

- Option 9 specific study requirements are:

  - A detailed study of the water quality implications of transferring large quantities of Trent water through the Witham, Ely Ouse, Stour and Pant/Blackwater.

- For all options it is recommended that each region undertake water resources simulation studies of the cumulative hydrological changes for all likely future schemes within their region.

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