

1989/042



TERRESTRIAL & FRESHWATER SCIENCES DIRECTORATE

Support for the Scottish Water Industry

**NERC Terrestrial and Freshwater
Sciences Directorate
Support for the Scottish Water Industry**

March 1989

NERC TERRESTRIAL SCIENCES DIRECTORATE AND THE SCOTTISH WATER INDUSTRY

TABLE OF CONTENTS

1	INTRODUCTION	
1.1	RESEARCH ORGANISATIONS SERVING THE WATER INDUSTRY	1
1.2	NERC TERRESTRIAL and FRESHWATER SCIENCES DIRECTORATE	2
1.2.1	Institute of Hydrology	3
1.2.2	Freshwater Biological Association	3
1.2.3	Institute of Terrestrial Ecology	4
1.2.4	Institute of Virology	5
2	PRIORITIES FOR RESEARCH	
	SUMMARY TABLE	
3	PROJECT DESCRIPTIONS	13
3.1	WATER RESOURCES	13
3.1.1	Applications of low-flow study	13
3.1.2	Flow regimes and biological factors	13
3.1.3	Management strategies for reservoir water quality	14
3.1.4	Effect of altitude on potential evaporation	15
3.2	FLOODS and LAND DRAINAGE	15
3.2.1	Update of Floods Studies Report	15
3.2.2	Flood forecasting	16
3.2.3	Weather radar in the alleviation of climatic hazard	16
3.2.4	Snowmelt flood forecasting	17
3.3	WATER QUALITY	18
3.3.1	Acidification of soils and water	18
3.3.2	Toxic chemical pollution in catchments	19
3.3.3	River water quality models	20
3.3.4	Impact of forestry on water quality	21
3.3.5	Nutrient enrichment	22
3.3.6	Predicting raw water colour	23
3.4	POLLUTION	24
3.4.1	Sediments	24
3.4.2	Effect on animals	25
3.4.3	Modelling of caesium	26
3.5	FISHERIES	26
3.5.1	Salmonid fish	26
3.5.2	Physiology of stress	28

3.6	ENVIRONMENTAL MONITORING and IMPACT ASSESSMENT	29
3.6.1	Environmental impact assessment (EIA)	29
3.7	CLIMATE CHANGE	30
3.7.1	Impact on water quality	30
3.7.2	Impact on low-flows	31
3.7.3	Implications of sea-level change	32
3.8	LAND-USE and HYDROLOGY	32
3.8.1	Effects of land-use change on water resources	32
3.8.2	Broadleaf afforestation in lowlands	32
3.8.3	Distributed modelling to assess effects of land-use change on catchment runoff	33
3.8.4	Multispectral remote sensing	34
3.9	URBAN HYDROLOGY	34
3.9.1	Effects of urbanisation on catchment response	34
3.9.2	Flood risk assessment with level affected outfalls	35
3.9.3	Remote sensing for urban hydrology	35
3.10	ENVIRONMENTAL DATABASES and DATA MANAGEMENT SYSTEMS	36
3.10.1	Environmental Information Centre (EIC)	36
3.10.2	National surface water archive	37
3.10.3	National water quality archive	38
3.10.4	National biological archive	38
3.10.5	National biological classification of rivers	39
3.10.6	Land use change in Britain	40
3.11	REGIONAL DATA ANALYSIS	40
3.11.1	Water information systems (WIS)	40
3.11.2	Digital terrain model (DTM) application in water resource management	41
3.12	TECHNOLOGY TRANSFER	42
3.12.1	Micro FSR	42
3.12.2	HYDATA	43
3.12.3	Micro-based water quality model	43
3.12.4	MAGIC	43

NERC TERRESTRIAL AND FRESHWATER SCIENCES DIRECTORATE AND THE SCOTTISH WATER INDUSTRY

1 INTRODUCTION

The purpose of this paper is to describe the activities of the NERC Terrestrial and Freshwater Sciences Directorate (TFSD) that are of direct interest to the Scottish Water Industry. At present commissioned research and applied studies are carried out by TFSD for private clients as well as Government Departments which in Scotland include the Scottish Development Department (SDD) and the Department of Agriculture and Fisheries for Scotland (DAFS).

The TFS Directorate has recently reviewed its research programme in the context of the future needs of the water industry throughout the UK. The objective of the review was to identify areas of high priority research where more effort is needed. In Scotland, subjects of particular concern are the acidification of surface waters and the effects of land-use change on water resources.

The strength of the TFS Directorate is that the programmes of fundamental research ensure that the Institutes have the skills, analytical techniques and experience to tackle many applied problems. TFSD also has considerable experience in Scotland where some of its Research Stations and experimental sites are located. Those parts of the existing programme of strategic research relevant to the interests of the water industry are described in Section 3. In addition to the existing projects, proposals for new projects, designed to meet specific problems, within the main project areas are also given.

The paper has been prepared by the Institute of Hydrology, with inputs from the other TFSD Institutes. More detailed proposals on any of the proposed research projects outlined in section 3 could be produced very quickly. Furthermore the TFSD Institutes are also able to assist in short-term applied studies. In the first instance readers requiring further information or assistance should contact Dr. A E Bailey-Watts at the Edinburgh Research Station of the Institute of Terrestrial Ecology (see Section 1.2.3)

1.1 RESEARCH ORGANISATIONS SERVING THE WATER INDUSTRY

The Natural Environment Research Council, established by Royal Charter in 1965, has responsibility for planning, encouraging and carrying out research in the physical and biological sciences which explain the natural processes of the environment. The three Directorates of NERC, Earth Sciences, Marine Sciences, and Terrestrial and Freshwater Sciences, all undertake research work that is of direct relevance to the regulatory and operational functions of the Scottish Water Industry. However this paper only identifies the research capabilities and programme of the Terrestrial and Freshwater Sciences Directorate.

In addition to the NERC Institutes, the main organisations that currently carry out water related research are the Water Research Centre and Hydraulics Research PLC. NERC has working relationships with both organisations, but their main fields of interest, and thus their research programmes, differ and are complementary. Some relevant research work is

also carried out by University departments. In a number of subjects NERC help to co-ordinate the national research efforts in Universities and Institutes through established liaison groups, Special Topic funding and through sub-contractors as part of departmental contracts.

1.2 NERC TERRESTRIAL AND FRESHWATER SCIENCES DIRECTORATE

The NERC TFSD brings together an exceptionally wide range of disciplines comprising one of the world's largest bodies of environmental expertise. The TFSD research programmes draw on staff whose disciplines include:

- botany
- chemistry
- computer sciences
- ecology
- ecotoxicology
- engineering
- forestry
- geography
- geology
- hydrology
- mathematics
- microbiology
- physics
- soil science
- virology
- zoology

The resources of TFSD are combined together into a comprehensive research programme that addresses national and international needs in three main areas:

- Ecology and conservation
- Environmental quality and pollution
- Land use and natural resources

The main TFSD Institutes concerned with activities relevant to the Water Industry are the Institute of Hydrology, the Freshwater Biological Association, soon to be renamed the Institute of Freshwater Ecology, and the Institute of Terrestrial Ecology. Some of the research undertaken by the Institute of Virology is also of relevance. In Scotland, TFSD Institutes have close links with the Department of Agriculture and Fisheries for Scotland, the Nature Conservancy Council and the Water Research Centre who are interested in surface waters per se, and with the Countryside Commission for Scotland, the Forestry Commission and the Macaulay Land Use Research Institute with interests in runoff.

The ten Research Stations of TFS, supplemented by Units in Universities and by field sites provide a strategic network of facilities and expertise covering the environmental variation of Britain. The network includes several Research Stations and experimental sites in Scotland.

1.2.1 Institute of Hydrology

The Institute of Hydrology (IH) has a broad programme of both fundamental and applied studies into the movement and behaviour of water in its translation from rainfall into runoff or evaporation. Specific projects range from understanding physical processes to the mathematical modelling of catchment behaviour for environmental and engineering purposes. Studies of water quality and pollution have become an increasingly important part of the research programme in recent years. A considerable part of the Institute's activities is funded as commissioned research and ensures that research activities are closely related to practical needs and that newly developed methods are tested for a wide range of environmental conditions.

The National Surface Water Archive is maintained at IH, containing data from almost 1200 gauging stations throughout the UK. In addition to the computer based data retrieval system, published yearbooks provide information on the availability and suitability of hydrological data to satisfy a broad-based demand within the UK and abroad.

This extensive data bank and many aspects of the IH research programme are particularly relevant to the study of the hydrological and water balance implications of climate change.

IH also has a strong interest in catchment studies in Scotland. These include the experimental catchment at Balquhider where the effects of afforestation are being studied, the Alt' Mharcaidh catchment which is part of the Surface Water Acidification programme and other catchments that are part of the UK Acid Waters Monitoring Network.

Institute of Hydrology
Wallingford
OXON OX10 8BB
Tel: 0491 38800

Balquidder Site
Tulloch Lodge
Balquidder
Lochearnhead
Perthshire FK19 8PQ
Tel: 08774 257

1.2.2 Freshwater Biological Association

The Freshwater Biological Association (FBA) was founded to promote fundamental research into biology and ecology of all kinds of freshwaters. It is soon to be renamed the Institute of Freshwater Ecology (IFE). Basic chemical and physical studies comprise an increasing part of the research programme, while biological studies include taxonomy, community structure, feeding behaviour, population ecology and physiology, and their relations with environmental variables both natural and man-induced.

The FBA also makes its information service available to the Water Authorities. This provides copies of the monthly current awareness lists of publications on freshwater biology and chemistry; an annual list of published papers relating to each Authority's area; and an immediate response service to telephone enquiries. The Scottish Regional Councils

and River Purification Boards may also find it useful to have access to these services.

Much of its commissioned work is directed towards the management of waters with regard to improved quality and fisheries status including the impact of nutrient load and land use thereon. Major developments include the development of models to assess the impact of perturbations on the function of freshwater systems.

Freshwater Biological Association
The Ferry House, Far Sawrey
Ambleside, Cumbria
LA22 0LP
Tel: 09662 2468

The River Laboratory
East Stoke,
Wareham
Dorset BH20 6BB
Tel: 0929 462314

1.2.3 Institute of Terrestrial Ecology

The Institute of Terrestrial Ecology's (ITE) main concern is the study of the factors determining the distribution and abundance of plant and animal species, and the structure and functioning of terrestrial ecosystems. This research is aimed at providing a sounder scientific basis for forecasting and modelling the environmental impacts of natural or man-made changes such as pollution or changes in land use.

ITE are also able to undertake detailed historical surveys to put current environmental considerations into perspective. The Environmental Information Centre provides databases on land resources, geographical information and the distribution of biological species and communities.

ITE has two laboratories in Scotland; the main site is the Edinburgh Research Station which specialises in atmospheric pollution and tree biology and aquatic biology. It also houses an IFE group of freshwater ecologists. ITE's interest in processes controlling the different types of land use are relevant in this connection, although the research is centred mainly on the Merlwood research centre in Cumbria. The Banchory Research Station specialises in upland ecology with interests in sport animals such as deer and salmon in the Highlands. Work has also been done on coastal protection in relation to oil development in the North Sea.

Institute of Terrestrial Ecology
Edinburgh Research Station
Bush Estate, Penicuik
Midlothian, EH26 0QB
Tel: 031 445 4343

Banchory Research Station
Hill of Brathens, Glassel
Banchory, Kincardineshire
AB3 4BY
Tel: 03302 3434

Merlewood Research Station
Grange over Sands
Cumbria LA11 6JU
Tel: 04484 2264

Monks Wood Experimental Station
Abbots Ripton,
Huntingdon
Cambs. PE17 2LS
Tel: 04873 381

1.2.4 Institute of Virology

The Institute of Virology undertakes research on viruses, in particular those that cause disease of arthropods and those that are transmitted by arthropods to other organisms. Viruses associated with mosquitoes, gnats, sandflies, ticks, wild birds and feral or domestic animals are under study, as well as viruses of trees and wild grasses. The Institute also studies the ecological importance of naturally occurring viruses both as regulators of populations of insect species in various ecosystems and as potential controllers of insect pests. There are programmes of research at the Institute involving genetic engineering and custom design of viral insecticides.

Institute of Virology
Mansfield Road
Oxford OX1 3SR
Tel: 0865 512361

2 PRIORITIES FOR RESEARCH

Through its research Institutes, the NERC TFS Directorate is making and will continue to make major contributions to the following areas of research:

- Water resources
- Floods and land drainage
- Water quality and effects of pollution
- Fisheries
- Environmental monitoring and impact assessment
- Climate change and its environmental implications
- Urban hydrology
- Environmental databases and data management systems
- Regional data analysis
- Technology transfer

The following section gives brief descriptions of existing and proposed projects in these general categories that are of direct relevance to the Scottish Water Industry and that fall within the expertise of the TFSD Institutes. For existing projects target dates for project completion are given, however in some cases the details of more than one project have been combined together under one project title. For proposed projects an

indication of the resources needed and the likely duration is given.

The following table summarises the main existing and proposed projects by programme area.

SUMMARY TABLE OF EXISTING AND PROPOSED PROJECTS
Scottish Water Industry

3.1 WATER RESOURCES

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client	Running totals Existing Proposed	
3.1.1	Compensation flows	57	3	1990	DoE		
3.1.2	Flow regimes & biological factors						
	Minimum ecological flows	16	-	1991	NCC		
		---				====	====
	Total	73				73	

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)	End	Client	Running totals Existing Proposed	
3.1.2	Flow regimes & biological factors						
	salmon migration	65	3				
	habitats in vegetated rivers	61	3				
3.1.3	Reservoir management strategies for water quality	40	3				
3.1.4	Effect of altitude on evapotranspiration	40	-				
		---				====	====
	Total	206				73	206

3.2 FLOODS and LAND DRAINAGE

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client	Running totals Existing Proposed	
3.2.1	Update of Floods Studies Report	110	ongoing		MAFF		
3.2.2	Flood forecasting	70	ongoing		MAFF		
3.2.3	Weather radar						
	weather radar & climatic hazards	55	3	1990	DoE/MAFF/CEC		
	local calibration	30	2	1989	TWA		
3.2.4	Snowmelt flood forecasting	4	2	1989	STWA		
		---				====	====
	Total	269				342	206

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)	End	Client	Running totals Existing Proposed	
3.2.4	Snowmelt forecasting						
	weather radar	40					
		---				====	====
	Total	40				342	246

3.3 WATER QUALITY STUDIES

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.3.1	Acidification						
1.	effects of acid rain	90	2	1990	CEC		
	biological effects	12	5	1990	NCC		
	aquatic pollution	44	3	1989	DoE		
	surface water acidification	83	4	1989	Royal Society		
	geochemistry	44	4	1991	Welsh Off		
2.	measurement of pH in freshwaters	13	5	1990	Royal Society		
3.	speciation of Al in natural waters	48	5	1990	CEC		
	reclamation of acid waters	29	5	1990	Br. Indust. Sand		
3.3.2	Toxic chemical pollution						
1.	impact modelling	50	5	1992	DoE		
3.	pesticide determination	55	ongoing		DoE/NCC		
3.3.3	River water quality models (QUASAR)	28	1	1989	SWWA		
3.3.4	Forest impact on water quality						
1.	monitoring water quality	87	3	1991	DoE/NERC		
2.	upland sediment studies	34	2	1989	For. Comm.		
3.3.5	Nutrient enrichment	65	ongoing		MAFF		
		---			NCC & others	====	====
	Total	682				1024	246
PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.3.2	Toxic chemical pollution						
1.	storm runoff	50	4				
2.	pesticide-sediment standards	40	2				
3.3.3	River water quality models	20	3				
3.3.4	Forest impact on water quality						
3.	forestry & water temperature	15	3				
3.3.5	Nutrient enrichment						
	long-term changes in nitrates	62	1				
	trophic survey of UK lakes	50	1		cost depends on number of sites		
	historic algal & nutrient cycles	35	2				
	contribution of fish to N budget	25	3				
	modelling phosphorus removal	20	3				
	livestock & water quality	25	2				
3.3.6	Predicting raw water colour	74	3				
		---				====	====
	Total	416				1024	662

3.4 POLLUTION

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.4.1	Sediments						
	2. pesticide-particle interaction	40	1	1989	DoE		
3.4.3	Modelling of caesium	10	2	1990	CEC		
	geochemistry of radionuclides	26	4	1990	DoE		
	radionuclides in vegetation & soil	250	5	1991	DoE/MAFF/SDD		
		---				====	====
	Total	326				1350	662

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.4.1	Sediments						
	1. quality criteria	40	3				
	2. organic pollutants in river sediment	37	3				
	3. pesticide-particle interaction	40	1				
	3. metal release from sediments	49	2				
3.4.2	Effect on animals						
	evaluation of micropollutants	110	3				
	zinc & stream ecosystems	33	3				
	insecticides & forest ecosystems	55	4				
3.4.3	Modelling of caesium	30	3				
		---				====	====
	Total	394				1350	1056

3.5 FISHERIES

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.5.1	Salmonid fish						
	population dynamics	51	22	ongoing	NERC		
	management & re-stocking of rare fis	50	5	ongoing	NCC		
3.5.2	Physiology of stress						
	stress responses in freshwater fish	118			MAFF		
		---				====	====
	Total	219				1569	1056

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.5.1	Salmonid fish						
	stock:recruitment relationships	40	5				
	competition between trout & salmon	40	3				
	stocked trout & natural salmonids	40	5				
	stochastic model for trout growth	40	3				
3.5.2	Physiology of stress						
	environmental stress & ecophysiology	30	*				
		---				====	====
	Total	190				1569	1246

3.6 ENVIRONMENTAL MONITORING and IMPACT ASSESSMENT

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.6.1	Environmental impact assessment (EIA)						
	EIA for oil industry	58	ongoing		BP		
	EIA on coastal barrages	20	ongoing		Various		
	EIA on land drainage & reservoirs	10	ongoing		Various		
	EIA methodologies	50	ongoing		NERC		
		---				====	====
	Total	138				1707	1246

3.7 CLIMATE CHANGE

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.7.3	Implications of sea-level change						
	coastal engineering protection	55		1989	EEC		
	vegetation for engineering	45		1992	AWA/NCC		
		---				====	====
	Total	100				1807	1246

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.7.1	Impact on water quality						
	effects on water quality	60	4				
3.7.2	Impact on low-flows	57					
		---				====	====
	Total	117				1807	1363

3.8 LAND USE and HYDROLOGY

EXISTING PROJECTS		Cost/yr	Duration	End	Client		
3.8.1	Land use change & water resources	105	10	1991	Various		
3.8.2	Broadleaf afforestation	100	4	1992	DoE		
3.8.3	Distributed modelling						
	IHDH R&D	60	6	1990	MAFF		
	remote sensing of grassland	15	2	1990	Various		
	remote sensing for habitats	35	1	1989	Various		
3.8.4	Multispectral remote sensing						
	vegetation physiology & stress	15	-	1990	NERC		
		---				====	====
	Total	330				2137	1363

3.9 URBAN HYDROLOGY

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.9.1	Urbanisation and catchment response	18	3	1990	MAFF		
	Total	18				====	====
						2155	1363

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.9.2	Flood risk assessment with level affected outfalls	50					
3.9.3	Remote sensing for urban hydrology	21					
	Total	71				====	====
						2155	1434

3.10 ENVIRONMENTAL DATABASES and DATA MANAGEMENT SYSTEMS

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.10.1	Environmental Information Centre	300	long-term		DoE & NCC		
3.10.2	National surface water archive	250	long-term		NERC		
3.10.5	National biological classification of rivers						
	RIVPACS	50	1		WAs jointly		
	natural & polluted river communities	170	4		DoE		
3.10.6	Land use change in Britain	400	ongoing		DoE/DEn/others		
	Total	1170				====	====
						3325	1434

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.10.3	National water quality archive	140	long-term				
3.10.4	National biological archive	150	long-term				
3.10.5	National biological classification of rivers						
	banding surveys	40	1				
	RIVPACS support	140					
	Total	470				====	====
						3325	1904

3.11 REGIONAL DATA ANALYSIS

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.11.1	Water Information systems	240	ongoing		MAFF		
3.11.2	Digital terrain models database & thematic studies	88	ongoing		MAFF		
	Total	328				====	====
						3653	1904

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.11.2	Digital mapping - low-flows & pollution	80	2				
	Total	80				====	====
						3653	1984

3.12 TECHNOLOGY TRANSFER

EXISTING PROJECTS		Cost/yr (k)	Duration (years)	End	Client		
3.12.1	Micro FSR	20	long-term		NERC		
3.12.2	HYDATA	20	long-term		NERC		
	Total	40				====	====
						3693	1984

PROPOSED PROJECTS		Cost/yr (k)	Duration (years)				
3.12.3	QUASAR: development into interactive micro-based model	25	2				
3.12.4	MAGIC	20					
	Total	45				====	====
						3693	2029

3 PROJECT DESCRIPTIONS

3.1 WATER RESOURCES

3.1.1 Applications of Low Flow Study

Problem :

The desired levels of compensation flows and decisions on abstraction licenses and discharge consents have rarely been based on objectively derived low-flow criteria. The IH Low Flow Study used data up to 1974 to define low-flow criteria, their method of calculation and estimation for ungauged catchments. Since then several extreme summer droughts have occurred, improved hydrological databases have become available, and more efficient computer-based regionalisation procedures developed.

Objective :

To update the low-flow estimation techniques in current use by the Water Industry to set compensation flows, abstraction licences, discharge consents, etc.

Description :

Existing techniques for low-flow estimation methods are being updated using new theoretical methods, the extended hydrological, soils and geographical databases now available, and also incorporating feedback on the previous methods from Water Authority users.

The low-flow estimation procedure for Scotland (supported by the SDD) is under revision using improved hydrological response map HOST (Hydrology of Soil Types). Additional improvements will arise from the preparation of a pc based design procedure Micro Low Flows.

Existing project	Av cost £k/yr	Duration Years	End	Client
Compensation flows	57	3	1990	DoE

3.1.2 Flow regimes and biological factors

Problem :

There are continual pressures to increase abstractions from rivers and aquifers, or to reduce compensation releases from reservoirs. Such changes in flow regime can affect the plant and animal life of the river downstream.

Objective :

To examine the relationships between flow conditions and existing flora and fauna to predict critical points at which shifts or deterioration in species abundance and diversity might be expected.

Description :

The FBA have carried out field and experimental studies to investigate methods of combining physical and biological approaches to setting minimum ecological flows. Existing expertise on salmon counting and tagging could be used to investigate the relationship between upstream movements of adult salmon and the velocity and discharge of the river. Broader studies could look at the relationships between particular flow conditions and the existing flora and fauna to predict critical points at which shifts in species abundance (e.g. nuisance algae) or deterioration in the diversity and abundance of fly life might be expected. The competitive balance between plant species and flows is amenable to an experimental approach under which the relationship could be defined with greater accuracy.

Existing project	Av cost £k/yr	Duration Years	End	Client
Min ecological flows	16	3	1991	NCC
Proposed projects	Av cost £k/yr	Duration Years		
Salmon migration	65	3		
Habitats in vegetated rivers	61	3		

3.1.3 Management strategies for reservoir water quality

Problem :

Deterioration of reservoir quality can occur if appropriate reservoir management techniques are not employed.

Objective :

To provide advice and water quality management strategies for individual reservoirs.

Description :

TFSD Institutes have combined their experience of lake mixing, surface water chemistry, and microbiology to contribute to the more effective management of water quality and the definition of optimum management strategies for reservoirs. This work could be extended to incorporate scientific answers to questions on nutrient stripping, fish management, aeration and the benefits of flushing.

Proposed project	Av cost £k/yr	Duration Years
Reservoir management for water quality	40	3

3.1.4 Effect of altitude on potential evaporation

Problem :

Regional estimates of potential evaporation in Britain are based on extrapolation of results from a sparse network of meteorological stations most of which are at low altitude. An accurate assessment of evaporation is necessary to estimate the water resource of a catchment. Existing guidelines postulate that evaporation decreases with altitude, but data from the Balquhider experimental catchment suggests that the opposite is true.

Objective :

To study the relationship between altitude and evaporation.

Description :

Sites of different land-uses at a range of elevations would be selected within the existing experimental catchments at Balquhider and appropriate monitoring networks installed.

Proposed project	Av cost £k/yr	Duration Years
Altitude & evaporation	40	3

3.2 FLOODS and LAND DRAINAGE

3.2.1 Update of Floods Studies Report

Problem :

Since publication of the Floods Studies Report (FSR) in 1975 there have been many advances in statistical methods of flood frequency analysis, and more data are available. FSR design techniques are in widespread use throughout the UK, but now require review and some revision.

Objective :

To incorporate the latest theoretical developments and most recent basic data into FSR design procedures.

Description :

The extensive floods database now available at IH, together with physical catchment data available from geographical information systems, are being analysed with the newest statistical techniques.

Existing project	Av cost £k/yr	Duration Years	End	Client
Update FSR & associated work	110	ongoing		MAFF

3.2.2 Flood forecasting

Problem :

Short-term flood forecasts based on rainfall data could be improved by incorporating flow data observed in real-time.

Objective :

To develop operational real-time flood forecasting systems that use inputs from both real-time rainfall and flow data.

Description :

IH are developing an operational real-time flow forecasting system which includes rainfall-runoff and channel routing elements and also represents the fluvial-tidal interface. The model forecasts are updated using telemetry to improve forecast performance.

The project involves the implementation of an operational system for a specific river basin. However, the general design of the system would be appropriate for other UK river basins.

Existing project	Av cost £k/yr	Duration Years	End	Client
Flood forecasting	70	ongoing		MAFF

3.2.3 Weather radar in the alleviation of climatic hazards

Problem :

The extreme rainfall that leads to damaging flooding can often be

localised and is difficult to measure using traditional methods. Weather radar allows continuous measurements of rainfall to be made in space and time. Major advances have been made in the last decade in the operational use of such data for flood warning and prevention. Much remains to be done.

Objective :

To improve methods of calibrating weather radar, and to investigate the use of weather radar, other climatic data and catchment characteristics from extreme events in order to improve forecasts, warnings and operational procedures.

Description :

An operational system is being developed to combine regional rainfall information derived from telemetry systems with weather radar data to give better updated rainfall estimates and short-term high resolution rainfall forecasts. The system is being incorporated into a computer controlled flood warning system. The system being developed would be suitable for widespread use.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Weather radar & climatic hazards	55	3	1990	DoE & others
Weather radar calibration	30	~	1989	TWA

3.2.4 Snowmelt flood forecasting

Problem :

Operational flood forecasting systems often perform poorly when snowmelt contributes to the flood hydrograph. This is partly due to poor representation of the snowmelt processes in the model and partly due to inadequate knowledge of the extent, depth and water equivalent of lying snow.

Objectives :

1. To improve the snowmelt component of flood forecasting models.
2. To improve determination of snow cover using weather radar, and after 1990, satellite microwave data.

Descriptions :

1. An appropriate snowmelt model is being adapted for use in an operational system. The aim is to produce a model that could be applied to other parts of the UK with little modification.

2. Precipitation would be estimated from weather radar and compared with observed data from heated raingauges complemented by data from a snow survey network. Calibration procedures would be developed from this comparison.

Existing project	Av cost £k/yr	Duration Years	End	Client
Snowmelt flood forecasting	4	2	1989	STWA
Proposed project	Av cost £k/yr	Duration Years		
Snowmelt measurement & weather radar	40			

3.3 WATER QUALITY

3.3.1 Acidification of soils and water

Problem :

The atmospheric deposition of sulphur and nitrogen compounds is altering the water chemistry and ecology of catchments throughout the UK. Such changes have caused a deterioration in water quality and catchment ecology and are thus a major concern to the water industry and environmental groups. TFS has provided leading research in acidification over more than a decade. However, further research is required to extend and refine the prediction of what types of catchment are susceptible to acidification, what extent and timescale of the problem is likely to be for a range of emission scenarios, and which land management practices are likely to ameliorate or exacerbate the problem. predict what types of catchment will be susceptible to acidification and what the extent and time scale of the problem is likely to be for a range of emission scenarios.

Many of the chemical processes of acidification are still poorly understood. Some new monitoring and analytical methods have been developed, but this research needs to be continued.

Objectives :

1. To develop models of the acidification processes to assess the effects on water quality, soil chemistry and ecology of land use changes (such as afforestation), changing deposition, or land management practices such as liming.
2. To improve analytical methods for studying water and soil chemistry.
3. To study the impact of aluminium on a number of animals.

4. To study the mobilisation and transfer of elements within soils and from soils to water.
5. To investigate methods of reversing acidification.
6. To maintain existing monitoring networks.

Descriptions :

1. Selected catchments in the UK (including 9 in Scotland) and elsewhere in Europe have been instrumented, and models of acidification developed. The models have been calibrated against field data and validated using paleoecological records. Biological and ecological surveys are also being carried out.
2. The measurement of pH in freshwaters is surprisingly inaccurate, and techniques are being developed for accurate measurement.
3. One effect of acidification is the speciation of aluminium. This and the impact of toxic aluminium on animal populations are being investigated. For example, egg shell thinning in dippers and its association with acidification is being examined.
4. Improved methods for reclaiming acid waters from industrial sites are also being developed.
5. A series of covered plot experiments using deacidified water to assess the speed and recovery of soil and stream waters are proposed.
6. Geographic information systems are being used to provide information on the vulnerability of catchments to acidification. A database has been established covering the whole of Wales and drawing on pedological and geological information and on land-use data in order to assess risks of acidification of surface waters. It is planned to extend this exercise to cover the whole of the UK.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Effects of acid rain	90	2	1990	CEC
Biological effects	12	5	1990	NCC
Aquatic pollution	44	3	1989	DoE
Surface water acidification	83	4	1989	Roy Soc
Geochemistry	44	4	1991	Welsh Off
Measurement of pH	13	5	1990	Roy Soc
Speciation of Al	48	5	1990	CEC
Reclamation of acid waters	29	5	1990	Brit Ind Sand

3.3.2 Toxic chemical pollution in catchments

Problem :

Diffuse toxic chemicals, including agricultural pesticides, enter rivers through surface and ground waters. Surface waters are also polluted by point sources from urban runoff, and domestic and industrial sewage effluent. The resulting pollution threatens water supplies, as well as the wildlife associated with the waterways.

Toxic chemicals such as DDE, HEOD, PCBs and mercury are concentrated in species at the top of the food chain. Study of the accumulation of toxins in such species can give a good overall indication of environmental

pollution which is difficult to assess using other methods.

Some pesticides and other toxins are accumulated in trace quantities in river sediment particles. Analytical procedures are difficult, and it is not easy to standardise results between laboratories.

Objectives :

1. To monitor the distribution and movement of pesticides on land, in surface and groundwater and in sediments, and to develop models of toxic chemical, pesticide and fertilizer runoff.
2. To establish the real long-term trends in toxin levels and to chart and evaluate their effects on wildlife.
3. Establish analytical standards for measurements of pesticides and other toxins, particularly in sediments.

Descriptions :

1. Field measurements are providing data for model development. The models will be available for strategic planning.
2. Surveys of the levels of important toxins in predatory birds (heron, kingfisher, great crested grebe) and others have been carried out for over 25 years and need to be continued.
3. Analytical procedures for selected toxic chemicals, particularly in sediments, are being reviewed and intercomparisons of various measuring laboratories made.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Impact modelling	50	5	1992	DoE
Pesticide determination	55	ongoing		DoE/ NCC
Proposed projects	Av cost £k/yr	Duration Years		
Pesticides in storm runoff	50	4		
Pesticide-sediment standards	40	?		

3.3.3 River water quality models

Problem :

In river catchments with complex flow regimes and where a wide range of options for both sewage discharges and supply abstractions are available, techniques are needed to give an objective and rapid assessment of changes in water quality during planning or operation so as to identify potential problems.

Objective :

To develop a numerical model of a river catchment to be used for the rapid assessment of water quality changes following major perturbations, and also for planning purposes.

Description :

A prototype system has already been developed and tested. It needs to be improved by adding extra components and a better user interface. The generalised model, once fully developed and tested, would have application for many UK rivers. The model could be used for operational as well as planning purposes and would provide optimal solutions whilst giving adequate environmental protection.

Existing project	Av cost £k/yr	Duration Years	End	Client
River water quality model	28		1989	SWWA
Proposed project	Av cost £k/yr	Duration Years		
Further development of models	20	3		

3.3.4 Impact of forestry on water quality

Problem :

Forestry and other changes in upland land use have contributed to the acidification and the consequent adverse ecological effects on soils and stream waters in upland Britain. Both drainage for planting and the disturbance caused by felling increase the particulate materials entering upland watercourses. This leads to a variety of ecological effects such as reducing growth of aquatic plants and making gravel unsuitable for salmonid eggs. Forestry practices also affect water temperatures and can lead to adverse chemical and ecological effects.

Objectives :

1. To study water quality changes in forest streams before, during and after an intensive forestation programme.
2. To study the effects of forestry on sedimentation and hence river ecology.
3. To study the disproportionate effect of forestry on temperature changes in water and the consequent release of some chemicals on the embryonic development of salmonid fishes, and the invertebrate food supply.

Descriptions :

1. Monitoring of water quality in experimental catchments during a cycle of forestry development.
2. Monitoring of erosion and sedimentation processes. Examination of the ecological consequences of increased sedimentation such as the reduction in growth of aquatic plants and making gravel unsuitable for salmonid eggs.
3. More detailed field and experimental studies of the changes in stream temperature and the chemical and ecological consequences would be carried out.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Forest impact on water quality	87	3	1991	DoE/ NERC
Upland sediment studies	34	~	1989	For C
Proposed project	Av cost £k/yr	Duration Years		
Forestry & water temperature	15	3		

3.3.5 Nutrient enrichment

Problem :

Nutrient enrichment of freshwater bodies has serious implications for water supply, wildlife and conservation. The impacts, in this regard, of 'new' industries such as fish farming and afforestation, need to be established, in addition to those of the more traditional activities associated with sewage disposal and agriculture. The ecological effects of runoff bearing increased levels of phosphorus and nitrogen (especially nitrate and ammonia) are considerable.

Some aspects of this eutrophication are reasonably well understood, for example the effects on microscopic plants (Algae) and higher aquatic vegetation. Processes relating to what controls the observed shifts in the concentrations of nutrients in running waters, and the concentration-flow relationship are not well defined. The effects of factors such as atmospheric inputs, groundwater contributions and climatic events, have still to be distinguished.

All standing waters are subject to COPA (Control of Pollution Act) and CEC directives and a national classification of water quality is needed. Phosphorus inputs to a few lakes in the UK have been reduced with varying results: the response by the sediments need further investigation before models adequately describing the behaviour of different types of freshwater can be developed.

Objectives :

1. To better understand the processes of eutrophication.
2. To establish an appropriate ranking procedure for water quality.
3. To provide objective methods for setting nutrient standards with

respect to environmental and water quality.

4. To assess the threat of intensive fish farming to local water quality, with particular emphasis on nitrogen species.

5. To predict rate of recovery of lake water quality following phosphate removal.

6. To assess the effects of various nutrient control scenarios on total inputs and their seasonality.

Descriptions :

1. A desk study of long-term nitrate records which show marked oscillations that may be related to changes in atmospheric nitrogen, groundwater levels, and climatic events.

2. To further develop recent studies in which a cost-effective method of ranking water quality based on total phosphorus and total inorganic nitrogen was developed.

3. An experimental study would be carried out on the levels of nutrients suitable for the maintenance of specific standards of environmental and water quality.

4. A nitrogen budget model for trout would be developed from existing information on food intake, metabolism and growth in relation to temperature and other variables.

5. It is proposed to develop a model to predict the recovery time of a lake following phosphorus removal.

6. Where sufficient data exists to allow a seasonal assessment, compare and contrast the effects of different control programmes.

Existing project	Av cost £k/yr	Duration Years	End	Client
Nutrient enrichment	65	ongoing		NCC & others
Proposed projects	Av cost £k/yr	Duration Years		
Survey of long-term changes in nitrates	62	1		
Trophic survey of UK lakes	50	1		
Historic algal & nutrient cycles	35	2		
Fish & the N budget	25	3		
Modelling phosphorus removal	20	3		
Effects of intensive livestock rearing on surface water quality	25	2		

3.3.6 Predicting raw water colour

Problem :

Discoloured water supplies may not meet the required standards and are often considered to be unacceptable by the general public. Research at one site has already shown that heather burning, drainage limitations, stocking densities and certain rainstorm events are all factors which

contribute to colour problems. A way of predicting in general terms the processes and catchment characteristics that lead to highly discoloured water is needed.

Objective :

To collate all available data on water colour, and to develop appropriate models.

Description :

All relevant data would be collated and the characteristics of those catchments susceptible to increases in water colour identified. Predictive models would be developed to show how soil properties, rainfall depth and chemistry, and land-use influence the concentrations of coloured organic compounds. The application of the models in planning upland management and land-use changes would be considered.

Proposed project	Av cost £k/yr	Duration Years
Water colour predictions & modelling	74	3

3.4 POLLUTION

3.4.1 Sediments

Problem :

Many organic compounds, including pesticides and detergents, become associated with sediments. Present techniques are unable to describe their transport in the sediments and predict the behaviour of classes of pollutants in different sediment mixtures and particle size groups. Similarly, metals are rapidly recycled at sediment-water interfaces, and traditional steady-state models underestimate the fluxes of metals.

Objectives :

1. To demonstrate how existing water quality guidelines relate to the development of sediment quality criteria.
2. To develop a general diffusion and adsorption model.
3. To develop two-dimensional, time-dependent flux models of metal release.

Descriptions :

1. The importance of selected lyophobic pollutants would be evaluated using a combination of laboratory and macrocosm experiments.

2. Appropriate field and experimental data would be used to develop new models.

Existing project	Av cost £k/yr	Duration Years	End	Client
Pesticide-particle	40	1	1989	DoE

Proposed projects	Av cost £k/yr	Duration Years
Quality criteria	40	3
Organic pollutants in sediments	37	3
Pesticide-particle interaction	40	
Metal release from sediments	49	

3.4.2 Effects on animals

Problem :

Little is known of the effects of sub-lethal concentrations of selected micropollutants on established communities of plants and animals. One example is the watercress industry which uses zinc for disease control, which becomes incorporated in the sediments, plants and animals downstream. Another example is the effect of insecticide used to control forest pests.

Objective :

To assess the effects of sub-lethal concentrations of selected micropollutants on established communities of plants and animals.

Description :

Recirculating experimental streams would be used to study the rates of uptake and loss of zinc and other micropollutants from the various components of the ecosystem.

Proposed project	Av cost £k/yr	Duration Years
Evaluation of micropollutants	110	3
Zinc & stream ecosystems	33	3
The fate of insecticides in freshwaters within forest ecosystems	55	4

3.4.3 Modelling of caesium

Problem :

There is some evidence that reservoirs with upland peaty catchments are now showing high caesium concentrations long after Chernobyl. This high vulnerability to radionuclide deposition following atmospheric pollution from any future Chernobyl-type incident needs further research.

Objective :

To identify appropriate monitoring procedures and to improve the validity of models of radionuclide transport.

Description :

The existing steady state planning model would be improved and used to predict freshwater caesium levels so that the uptake by algae, invertebrates and fish can be assessed following any future incidents.

The research would build on the studies on post-Chernobyl transfers of caesium into and sedimentation within lakes carried out by FBA and ITE and on the intensive studies of caesium mobility in different soil-vegetation-animal systems.

The principles developed for caesium transport can be extended to other radionuclides, based on their known physical chemistry and on the known system priorities which determine element dynamics.

Existing project	Av cost £k/yr	Duration Years	End	Client
Caesium modelling	10	2	1990	CEC
Geochemistry of radionuclides	26	4	1990	DoE
Radionuclides in vegetation and soil	250	5	1991	DoE, MAFF SDD
Proposed projects	Av cost £k/yr	Duration Years		
Caesium transport model	30	3		

3.5 FISHERIES

3.5.1 Salmonid fish

Problem :

Studies of the effects of changes in flow regimes and land management on

salmonid fish in the Lake District, Pennines and the River Frome (Dorset) have been undertaken for over 20 years. They have provided a continual source of advice and need to be maintained and supplemented by additional projects in order to keep up with the latest developments. Other work of UK-wide relevance carried out in northern Britain focuses on the status of rare British freshwater fish.

Objectives :

1. To maintain existing long-term records on salmonid populations.
2. To investigate stock:recruitment relationships of salmon in a southern river.
3. To determine the degree of competition between young salmon and young trout.
4. To assess the density dependent relationship between stocked rainbow trout and natural populations of salmonids.
5. To develop a stochastic model for predicting growth of trout in relation to varying water temperatures.
6. To assess the distribution of rare fish and, if appropriate, develop a management strategy for their re-stocking in suitable habitats.

Descriptions :

Existing long-term records will be continued . The existing data on adult salmon in the River Frome would provide a basis for developing other studies on factors affecting this species. The installation of a smolt trap would establish a year-to-year relationship between the number of adult fish entering the river to spawn and the numbers of smolts migrating to the sea.

The growth rates and mortality of trout and salmon fry will be determined in experimental channels stocked at three different densities. Brown trout and rainbow trout will be maintained in experimental channels to assess the relative impact of increasing density with brown trout or with rainbow trout.

The FBA has a single deterministic model of trout growth which will be improved into a stochastic model. The brown trout is widespread in Europe and such a model could be used as a management tool to assess the effects of climate change or other factors affecting temperature regimes.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Population dynamics of brown trout	51	22	ongoing	NERC/MAFF
Management and re-stocking of rare fish	50	5	ongoing	NCC

Proposed projects	Av cost £k/yr	Duration Years
Stock:recruitment relationships of salmon	40	5
Competition between young salmon & trout	40	
Relationship between stocked trout & natural salmonids	40	
A stochastic model for trout growth	40	

3.5.2. Physiology of stress

Problem :

Several years ago, the FBA built extensive rearing and holding facilities for experimental studies on fish. These have been used mainly for studies of endocrine physiology, particularly to understand the effects of stress on trout. Substantial and persistent endocrine disturbances can be caused which can offset, for example, susceptibility to disease. Existing studies on stress in trout are now at a stage where they could be extended to the effects of stresses on salmonids in the natural environment such as spates, acid pulses, droughts or sublethal pollution.

Objectives :

1. To monitor seasonal physiological changes in natural populations of salmonid fish in a range of environments.
2. To examine the effects of environmental stresses and determine appropriate parameters of fish health for use in detection of potential environmental problems.

Descriptions :

1. Natural salmonid populations will be sampled and blood samples obtained for cortisol determination and blood cell counts. Records of weight, length, age, sex, etc. will also be made.
2. Established methods will be used to measure the levels of chronic stress in the populations.

Existing projects	Av cost £k/yr	Duration Years	End	Client
The physiology of stress responses	118	4		MAFF

Proposed project	Av cost £k/yr	Duration Years
Environmental stress & ecophysiology of fish	30	3

3.6 ENVIRONMENTAL MONITORING and IMPACT ASSESSMENT

3.6.1 Environmental impact assessment (EIA)

Problem :

Recent CEC directives now require EIA as an integral part of the planning process for major developments. Many scientists from a wide range of disciplines may be required to contribute to major EIA. Inputs require careful consideration and there is always the concern that independent interdisciplinary issues are not overlooked.

As the CEC directives have been under discussion for several years many developers have already demanded EIA and TFSD has acquired considerable ad hoc experience in carrying out such appraisals. During this work it has become clear that improved methods are required.

The Terrestrial and Freshwater Sciences Directorate of NERC has established a Task Force to examine the best way of identifying EIA problems and of mounting scientific teams to address these. A number of specific research investigations have begun.

Objective :

To develop an EIA methodology which addresses the requirements of the CEC directive for major developments projects.

Description :

TFSD is involved in very specialised aspects of EIA projects being carried out for developments such as the Channel tunnel, onshore oil development in Dorset, estuarine barrages, siting of water storage reservoirs and land drainage schemes.

Existing project	Av cost £k/yr	Duration Years	End	Client
EIA for oil industry	58	ongoing		BP
EIA on coastal barrages	20	ongoing		VARIOUS
EIA on land drainage and resevoir sites	10	ongoing		VARIOUS
Development of EIA methodology	50	ongoing		NERC

3.7 CLIMATE CHANGE

Problem :

There is now a scientific consensus that increasing concentrations of atmospheric pollutants will lead to global warming and changes in rainfall and evaporation. However there is much debate and scientific uncertainty on what the consequences of climate change are likely to be, and in particular how the aquatic environment will be affected.

The current TFSD programme on climate change, which is being carried out in collaboration with other agencies such as the UK Meteorological Office, comprises three main elements :

assessing the extent of climate change by comparing the existing climate with long-term meteorological and hydrological records.

interpreting likely climate change scenarios as predicted by Global Circulation Models (GCM).

impact studies aimed at identifying the possible effects of climate change as predicted by GCMs on the natural environment.

3.7.1 Impact on water quality

Problem :

The interactions between hydrology, water quality and terrestrial systems are extremely complex and involve many feedback mechanisms. Water quality is an essential component of water resource management and maintenance of the fluvial environment. Water quality is dependent on many factors such as rainfall, river flows, temperature, animal and plant growth rate, survival and so on, all of which will be affected by climate change. The likely impact of climate change on these factors needs to be quantified.

Objective :

To develop models to link water quality with climate change, and to assess the modelling and statistical techniques for the analysis of trends.

Description :

Climate change scenarios from Global Circulation Models would be used to determine the possible effects of climate change on water quality. The studies on water quality will be linked with current and proposed research in TFS on the impact of climate change on land use, vegetation and management.

Proposed project	Av cost £k/yr	Duration Years
Effects on water quality	60	4

3.7.2 Impact on low-flows

Problem :

There have been suggestions that the occurrence of droughts over the period 1972-1984 has been due to climate change rather than the natural year-to-year variability in climate.

Objective :

To study the recent pattern of extreme hydrological events and the relationship between historical changes in low flows and fluctuations in the mean northern hemisphere climate.

Description :

Progress has been made on understanding the links between low flow characteristics and climate variables, which will allow the possible effects of climate change on flow regime to be assessed.

Proposed project	Av cost £k/yr	Duration Years
Impact on low-flows	57	4

3.7.3 Implications of sea-level change

Problem :

Climate change, the associated rise in sea level, and also industrial development have serious implications for coastal protection and sea defences as well as the local ecology. Potential pollution problems may result from reworking of sediments.

Objective :

To assess ecological effects of rises in sea-level due to climate change and the possible consequences on sea-defences, and to examine the possibilities of using vegetation as a supplementary form of coastal defence.

Description :

ITE are undertaking various ecological studies on salt marsh processes in collaboration with Dutch, French and Portuguese scientists. They are also represented on the review panel considering work on land use, coastal morphology and geography.

Existing projects	Av cost £/yr	Duration Years	End	Client
Coastal erosion protection	55	4	1989	EEC
Vegetation for engineering	45	7	1992	AWA /NCC

3.8 LAND USE and HYDROLOGY

3.8.1 Effects of land-use change on water resources

Problem :

Little was known about the effects of upland afforestation on catchment yield and water quality before IH started a number of catchment research projects in the 1960s. In some catchments it has been shown that afforestation can cause a reduction in runoff of up to 15%. Such a reduction would have important consequences for water resources, so the issue needs to be kept under continuous review.

Objective :

To assess the effects of upland forestry management on both water quantity and quality.

Description :

Continued monitoring will allow the further development of comprehensive models for the prediction of the effects of land-use change on water resources, quality, and sedimentation.

Existing project	Av cost £k/yr	Duration Years	End	Client
Land-use change & water resources	105	10	1991	NERC

3.8.2 Broadleaf afforestation in lowlands

Problem :

It is expected that broadleaf plantation in lowland and marginal land areas of Britain will increase significantly over the next few years in response to changes in agricultural policy. The precise effects of this type of land use change on the hydrology and chemistry of lowland catchments are not clear.

Objective :

To establish the chemical and hydrological processes of broadleaf plantations in the UK lowlands.

Description :

Detailed experiments of evaporation and the water relations of broadleaf plantations are being carried out, from which the effects on water resources and quality can be deduced. The hydrology and chemistry studies will build in terrestrial research on planting options for broadleaved woodlands and their effects on evapotranspiration and soil water chemistry.

Existing project	Av cost £k/yr	Duration Years	End	Client
Broadleaf afforestation	100	4	1992	DoE

3.8.3 Distributed modelling to assess effects of land-use change on catchment runoff

Problem :

It is difficult to predict the likely effects of land-use change. However distributed models, such as the IH distributed model (IHDM), whose parameters are based on physical characteristics have considerable potential and could be developed further.

Objective :

To investigate the potential of the IHDM in predicting runoff from small catchments, and also predicting changes in runoff regime caused by land-use changes and different land management practices.

Description :

The IHDM allows different land-uses to be represented with parameters based on physical characteristics. The use of remote sensing and documentary evidence allows historical changes in land-use to be quantified and used in predictive models. When linked with land-use and vegetation mapping and monitoring, the models can be verified and used to study major water resource development schemes.

Existing projects	Av cost £k/yr	Duration Years	End	Client
IHDM R & D	60	6	1990	MAFF
Remote sensing of grassland and land cover mapping	15	2	1990	Various
Remote sensing for habitats	35	1	1989	Various

3.8.4 Multispectral remote sensing

Problem :

It is notoriously difficult to accurately assess the chemical inputs to grassland on a catchment level. However it has been shown that multispectral remote sensing could provide useful quantitative information not available from traditional methods. In addition to recording land cover within catchments, multispectral remote sensing can also provide information on the condition of vegetation.

Objective :

To investigate the potential of airborne multispectral radiometers and spectrometers for estimating application levels of agricultural chemicals to grassland.

Description :

Multispectral remote sensing, in addition to recording the nature of land cover within catchments can in principle provide information on the condition of vegetation by observing the plant response of canopies at different spectral frequencies. ITE is investigating the potential use of airborne radiometers and spectrometers to assess the quantity of agricultural chemicals such as lime and nitrogen-based fertilizers applied to grassland.

Existing projects	Av cost £k/yr	Duration Years	End	Client
Vegetation physiology and stress	15	3	1990	NERC

3.9 URBAN HYDROLOGY

3.9.1 Effects of urbanisation on catchment response

Problem :

Urbanisation has a marked effect on flood magnitude and frequency, which may be important for problems of river basin management, and in particular the design of river works and storage ponds downstream of urban areas. The present techniques for quantifying the effects of urbanisation on catchment response could be improved by further research.

Objective :

To investigate the significant aspects of urban development responsible for these changes, and to develop models to predict these changes on ungauged catchments.

Description :

A new subcatchment hydrological event model is being developed to assist engineers in planning and design studies.

Existing project	Av cost £k/yr	Duration Years	End	Client
Urbanisation & catchment response	18	3	1990	MAFF

3.9.2 Flood risk assessment with level affected outfalls

Problem :

Most outfalls and overflows from sewer systems can be affected by backwater from high levels in receiving waters. Current predictions of global climate change imply that there will be significant rises in sea level that will affect the viability of many drainage systems. At present there is no widely available methodology for assessing the detrimental effects of sea-level rise on a given drainage system.

Objective :

To develop computer software and guidance for drainage engineers to assess the risks of flooding and restricted flow in sewers subject to tidal and other downstream influences.

Description :

Fluvial and coastal catchments with concurrent time-series of rainfall and downstream levels would be selected. The data would be analysed to develop appropriate risk assessment procedures that would be implemented in a software package.

Proposed project	Av cost £k/yr	Duration Years
Flood risk assessment with level affected outfalls	50	2

3.9.3 Remote sensing for urban hydrology

Problem :

In the past estimates of different land use in urban areas has been based on expensive ground surveys. Research is needed to develop remote sensing techniques for carrying out effective and accurate land use surveys. Better estimates of impervious areas will be invaluable for the planning and design of cost effective urban drainage and sewage systems.

Objective :

To compare remotely sensed impervious area estimates with those derived from ground surveys.

Description :

The resolution of remotely sensed data now means that surveys of land-use, and in particular impervious areas, in urban areas can be carried out accurately and efficiently. Selection of suitable urban catchments for study will be based on the availability of appropriate data. Differences between remote-sensing derived results and ground truth data will be compared to assess the achieved accuracy.

Proposed project	Av cost £k/yr	Duration Years
Remote sensing for urban hydrology	21	3

3.10 ENVIRONMENTAL DATABASES and DATA MANAGEMENT SYSTEMS

3.10.1 Environmental Information Centre

Problem :

Research into the natural environment is critically dependent on the existence of relevant high quality data that can be easily accessed. Although there are many sources of relevant data the data are stored in many different locations and in a variety of forms. The collation of all relevant information for a specific research or applied project is often far from straightforward. The archiving of environmental data needs to be improved if the best use of available information is to be achieved.

Objective :

To maintain a national environmental database.

Description :

The NERC TFSD is unique in Britain in the volume and extent of the environmental data it holds, and in the sophistication of the management systems for data interrogation and analysis.

The Environmental Information Centre (EIC) has recently been established as a focus for the acquisition, storage and dissemination of data and information on the terrestrial environment. The EIC includes three operational groups; remote sensing for land resource assessment; digital geographic information systems; Biological Records Centre. All aspects of the EIC work are of potential relevance to research into river management.

Existing project	Av cost £k/yr	Duration Years	End	Client
Environmental Information Centre	300		long-term	DoE & NCC

3.10.2 National surface water archive

Problem :

River flow data are necessary for all aspects of river basin planning and management. The demands for data range from small sets of local data, to the very large data volumes required to service the operational and design functions of the water industry as well as national and international research programmes. Whilst data are collected by separate authorities it was considered necessary to set up a centralised archive charged with providing a comprehensive service of data publication and retrieval for all potential users.

Continued support of the archive, and the associated research and development programme, is essential if the accurate hydrological data and statistics required for present planning and operational purposes are to be efficiently provided.

Objective :

To maintain the existing facilities provided by the national surface water archive, to enhance the retrieval options and to ensure publication of the Hydrological Yearbook by October of the following year.

Description :

Stewardship of the National Surface Water Archive was transferred to IH in 1982. A comprehensive suite of standard and more specialised retrieval techniques has been developed to meet the broadly based demand for river flow data. The existing facilities offered by the archive will be supported and enhanced to make the best use of newly developed technologies such as digital mapping, graphical systems and also allow on-line access.

Existing project	Av cost £k/yr	Duration Years	End	Client
National surface water archive	250		long-term	NERC

(note this is a statutory duty under the 1973 Water Act that has been passed from DoE to NERC by a permanent PESC transfer)

3.10.3 National Water Quality Archive

Problem :

River water quality is becoming an increasingly important issue for water supply as well as environmental concerns. To date no comprehensive national water quality archive has been compiled although many organisations monitor quality both on a routine and a project specific basis.

Objectives :

- 1) To make comprehensive and consistent sets of water quality data available in printed and computer compatible form that will complement the existing surface water archive.
- 2) To assist with compilation and publication of the results of the 1990 River Water Quality Survey using digital river network mapping techniques.

Description :

A quality archive would be operated in the same way as the flow archive, in that the project would be responsible for assembling, checking, storing and publishing the data collected by the various agencies that operate quality networks.

Her Majesty's Inspectorate of Pollution (HMIP) have been responsible for the online Harmonised Monitoring Archive; there have been suggestions that this might be integrated with the Surface Water Archive at IH, who already publish a small sample of key river quality information.

Proposed project	Av cost £k/yr	Duration Years
National water quality archive	140	long-term

3.10.4 National biological archive

Problem :

Many biological data for UK rivers exist. These data are of immediate use for water quality and conservation, and also provide a baseline against which any future changes can be assessed. However there are many important data sets that could be made more widely available if a comprehensive archive were to be set up.

Objective :

It is proposed that the Biological Records Centre (BRC) provide the archive for all information on the distribution of freshwater organisms, which would complement existing surface water archives and the proposed water quality archive.

Description :

The expertise of FBA and their existing biological data archive would be linked to the BRC scheme to form the basis of a national archive on freshwater organisms.

Proposed project	Av cost £k/yr	Duration Years
National biological archive	150	long-term

3.10.5 National biological classification of rivers

Problem :

The ranking of rivers on the basis of water quality and biological indicators is an important component of the national river quality survey. The FBA have devised a classification system for predicting the species to be expected at a given site from its physical and chemical conditions. This system would be a very effective way of improving the coverage of the biological information to be included in the next River Water Quality Survey.

Objective :

To develop a banding system for biological quality on a national basis.

Description :

The FBA has gathered detailed information about the invertebrate communities at many sites on 77 rivers in mainland Britain. The system will form part of the next River Water Quality Survey, and is being adapted for use on microcomputers. Comparison of indices designed to assess river water quality on the basis of chemical and biological criteria respectively will also be carried out.

Existing projects	Av cost £k/yr	Duration Years	End	Client
River invert. prediction classification system RIVPACS	50	1		WAs jointly
Natural & polluted river communities	170			DoE/Others

Proposed projects	Av cost £k/yr	Duration Years
Banding system for quality surveys	40	1
Support for RIVPACS	140	2

3.10.6 Land use change in Britain

Problem :

Land use in Britain has been changing but statistics are scattered. Future changes are likely to occur by their geographical distribution and ecological consequences, including hydrological and hydrochemical, need to be assessed for planning. ITE undertook a national survey, based on stratified sampling of 32 land classes, in 1978 and again in 1984. A repeat survey is planned for 1990 to continue assessment of change in land use and land cover. The data base has been widely used in analysis of actual and potential change in land management, alternative crops and environmental impact assessment.

Objective :

To determine the rate, type and distribution of land use change in Britain and its environmental consequences.

To maintain a data base for application in planning and research.

Description :

The data base developed from the previous surveys will be expanded by further field sampling, both in time and space. Integration with the recently established Environment Information Centre (3.10.1) is a high priority and collaboration with the river communities (3.10.5) and other water data bases is a logical development.

Existing project	Av cost £k/yr	Duration Years	End	Client
Land use change and ecological impacts	400	ongoing		DoE, DEn & others

3.11 REGIONAL DATA ANALYSIS

3.11.1 Water information systems (WIS)

Problem :

Maps are a fundamental source of physical data for hydrological analyses, however only a fraction of the information potentially available can be taken manually from maps. Conversion of maps to digital form allows much more information to be abstracted from the maps and makes many new approaches to hydrological analysis possible. Continued research is essential if the best use of the available techniques is to be made.

Objective :

To make geographical information systems technology available for a wide range of water related studies.

Description :

At present improvements are being made to the techniques for data capture, validation and storage, from which new methods to analyse and interpret catchment characteristics will follow. Such thematic information in digital form is becoming indispensable for developing improved methods of flood and low-flow estimation.

Existing project	Av cost £k/yr	Duration Years	End	Client
Water information systems	240	ongoing		MAFF

3.11.2 Digital terrain model (DTM) application in water management

Problem :

The UK-wide digital terrain model of a 50m X 50m grid of heights now gives a complete 3-D description of the land surface in a form suitable for digital analysis. Other physical information for soils, land-use and geology need to be digitised and incorporated into the database so that a large number of catchment characteristics can be accurately and efficiently derived for any point in a river network.

Objective :

To establish a set of techniques for combining and interpreting digital cartographic data together with key environmental data sets for low-flow estimation and pollution forecasting.

Description :

The results of this type of work have important implications in the estimation of flow characteristics at ungauged sites and thus will be vital for setting the consent conditions of effluent discharges. In combination with flow and water quality data, the digital information will make possible the automatic production of river quality and other types of map.

Existing project	Av cost £k/yr	Duration Years	End	Client
Database operation & thematic studies	88	ongoing		MAFF

Proposed project	Av cost £k/yr	Duration Years
Digital mapping for low-flow pollution	80	3

3.12 TECHNOLOGY TRANSFER

Problem :

Many analytical techniques and data processing procedures developed in the course of scientific research programmes could have widespread application in the water industry. This may also be true of programs and techniques developed in individual Water Authority offices. There is a need to promote the transformation of specialist computer programs into coherent user friendly and well documented software packages.

Objective :

To make various analytical techniques and software packages developed during scientific research programmes into more generalised user-friendly packages for use throughout the UK water industry.

Description :

To date programs from individual sections within IH have been developed into professional software packages; this approach could be extended to other organisations such as the NRA.

3.12.1 Micro FSR

Description :

The Flood Studies Report (FSR) techniques are in widespread use in the UK. The design procedure has now been incorporated into PC based software - Micro FSR - that contains the latest supplementary reports. Future developments are aimed at linking micro FSR to the a digital map database, so that abstraction of catchment characteristics may be automated.

Existing project	Av cost k/yr	Duration Years	End	Client
Micro FSR	20	long-term		NERC

3.12.2 HYDATA

Description :

HYDATA is a micro-based hydrological database and data processing system, designed for a wide range of users concerned with the storage, checking, presentation and analysis of hydrological data. It is especially useful for project studies.

Existing project	Av cost £k/yr	Duration Years	End	Client
HYDATA	20	long-term		NERC

3.12.3 Micro-based water quality model

Description :

The QUASAR water quality model was developed by IH for a specific application. There is a need for a more generalised model for use on micro and mini computers, to allow regional offices to model water quality problems for use in planning and operational studies.

IH is further developing a water quality model to handle both continuous and intermittent point and diffuse sources of pollution. The model is structured to ease transfer to other river basins, and to run on a range of microcomputers. It has general purpose application for both operational and planning purposes, with external variables being set by the user for the chosen basin and application.

Further developments to give an interactive, menu driven model with extensive graphics would allow the model to be used by pollution inspectors and planning officers at regional NRA centres.

Proposed project	Av cost £k/yr	Duration Years
Develop micro based quality model	25	2

3.12.4 MAGIC

Description :

MAGIC (Model of Acidification of Groundwaters In Catchments) is a user friendly programme for simulating long term changes in acidification. It can be used to assess the effects of changing deposition levels from atmospheric pollution and from changing land use such as afforestation.

MAGIC is currently being applied to many catchments in the UK, but further development of the software and documentation is necessary if it is to be made more widely available and of greater use to regional authorities.

Proposed project	Av cost £k/yr	Duration Years
Micro-based MAGIC	20	2