LONG TERM WATER RESEARCH REQUIREMENTS COMMITTEE

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Department of the Environment

April 1986

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FOREWORD

The House of Lords Select Committee on Science and Technology, from one of whose recommendations this report sprang, has repeatedly stressed the need for long term or strategic research. Such research provides a body of knowledge relevant to the management of resources and solution of problems, even though it does not specifically address issues of immediate concern. When funds for research are limited, there is a danger that such strategic work will be neglected in favour of more precisely targeted studies of immediate relevance. The Select Committee was concerned that this might be the case with research on water, by both the water industry and Government. They were also concerned that divisions of responsibility might lead to a less coherent overall strategy than is desirable.

The development and management of water resources is, of necessity, long term business. Demands for supply change over decades: standards of quality likewise require adaptation as knowledge and social standards alter, and freshwater ecosystems themselves adjust to varying physical and chemical conditions over long periods. The investment required to create new supplies, treat discharges more effectively or renew distribution networks is large and it takes a long time to plan and commission new installations. The costs of error can be high.

All these are reasons why the industry and Government need a long term research strategy as a basis for planning and executing their long term operational strategy. And Government, industry and the research community have to work in partnership because each has its proper role. The industry is required to provide water services in the most efficient manner. It is also required to maintain water quality in rivers, lakes, estuaries and the coastal seas. The emphasis here is on research that can be applied to give good value for money. The Government has to set standards, determine performance targets, and monitor how well the industry is meeting them. For this it needs knowledge of what is required to sustain human and ecological health, scientific understanding of the functioning of aquatic systems, and a realistic judgement of the likely effects of the industry's policies and practices. The research community is concerned, at one end of the spectrum, with the inherent scientific interest of aquatic systems and at the other with the potential for developing and marketing practical devices for use by the water industry. All need long term vision to plan and develop their activities.

Our Committee was chosen to reflect this diversity of interests. Our members were drawn from Government, water authorities, the Water Research Centre, consultancies

and the wider research community. We covered a wide range of scientific and engineering disciplines. Not surprisingly, our perspectives varied, and at times led to differing judgements. For example some members would have liked to see a different balance in the Report, with less emphasis on ecology and more on engineering. We all agreed that the socio-economic context within which the water industry will evolve needs to be understood if long term planning is to be done soundly, but we differed somewhat about the priority to be given to evaluating the socio-political context, which some saw as a "major research need" and others as important but of lesser priority. Such debates are natural, and our report is an inevitable compromise.

One significant change in context is likely to arise as a result of the proposals for privatisation of the water authorities which Government announced as we were coming to the end of our study. We did not consider that these proposals would significantly affect our research recommendations though arrangements for monitoring progress will need to be re-examined as privatisation approaches.

We would have wished to place costs on our recommendations. To do so with precision would, however, have meant a lot of detailed analysis. Rough calculations by some of us suggest that our major recommendations might cost £2 million per annum for 5 years, and our other proposals an additional £1 million per year over the same period. The implication is that we would add a little over 5% to what we calculate as the national total research effort in this field. But it need not all be additional. We expect that as the funding agencies review our work they will be able to adjust their programmes so that some existing projects of lower priority are replaced by new work in the areas we have highlighted. The true extra costs of our proposals cannot therefore be predicted - except that we would expect them to be modest.

One thing we agreed on is that the cost of ignorance in this field could be high. Misplaced investment, inappropriate standards, mis-match between demand and supply, or failure to foresee and guard against unacceptable environmental damage can all be very expensive. Research has a visible cost, inevitably committed against an uncertain benefit. It is generally impracticable to estimate what the cost of <u>not</u> doing the research will be - or to assess the risk of problems whose existence is unknown. But there are enough examples of the costs of mistaken judgement to satisfy us that the increased effort on long term research proposed in these pages is fully justified.

As Chairman, I commend this Report on behalf of my colleagues to Ministers, the water industry and the research community. I believe it will prove of value in shaping the future of our national water resources and water services. Finally, I record with pleasure my appreciation of the help I have had from all members of the Committee

over the past 18 months. On their behalf as well as my own I thank our Secretary, Mr J F Bonsall, for his labours, and also Dr David Watson who stood in at a critical period during Mr Bonsall's absence on other duties.

M W HOLDGATE
CHIEF ENVIRONMENTAL SCIENTIST

APRIL 1986

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SUMMARY

1. The Long Term Water Research Requirements Committee had its origins in the recommendations of the House of Lords Select Committee on Science and Technology. It met 8 times between May 1984 and December 1985.

2. In this report we review the need for research on:

(a) longer term issues affecting the water authorities and other water undertakers;

(b) other longer term problems of water policy including those relating to water conservation, the aquatic environment and public health.

We also examine the current organisation of water research in the UK to assess its capacity to respond to longer term needs.

3. The Committee has concentrated throughout on identifying areas of weakness rather than making detailed proposals for research. **Our general conclusion is that at present there are no major gaps in current and projected research but that a change of emphasis and some expansion of effort is required in several areas.** Provisional estimates suggest that our recommendations are broadly equivalent to 5% of the total water research budget but more detailed study of possible programme adjustments is required to assess the overall implications. The pace of social change and scientific and technological advance is such that gaps could appear in the future and we therefore feel that long term research needs should be reviewed in about 4 years.

Recommendations

4. Our **major** recommendations are set out below under two headings:

a. Environmental Research

b. Engineering and Processes Research.

The first of these categories covers the whole range of phenomena about which Government and industry need to know if they are to plan sensibly for the future. The research fields involved span almost the whole range of the environmental and social sciences. A proportion of the studies required can be undertaken within the Water

Research Centre or by individual water authorities. Much more forms part of the wider development of the environmental sciences for which we look to the Research Councils (especially NERC and ESRC) and the academic community.

The second area covers the technological developments the water industry must attend to in response to the changing context of its operation. A good deal of this research will fall to the industry itself, although SERC, NERC and some universities, and also private sector firms, can make substantial contributions.

We have used our best judgement in selecting our major recommendations, accepting the inevitable subjectivity of this approach. We have tried especially to identify areas where research is likely to produce significant financial rewards or contributions to the quality of life; we have also considered the urgency of the problems and the practicability of solving them using the research techniques currently available.

A list of all our recommendations is set out in Chapter 7.

5. Environmental Research

Our major recommendations are:

Environmental Protection

- Study the merits and investment implications of combining an EQO/EQS approach with emission limits for black list materials(2.7).

- Study dispersion and neutralisation mechanisms and develop predictive models for hazardous substances (2.8).

- Expand basic research on the physiological and biochemical responses of aquatic organisms to pollution in the context of long term investigations of their population performance (2.10).

Drinking Water Quality and Health

- Identify non-volatile organics in potable water (2.14).

- Investigate effects of distribution systems on chemical quality (2.14).

	• Continue work on basic toxicological and medical research (2.17, 2.19).
	• Examine effects of water treatment on pathogenic viruses and protozoa (2.20).
Social and Economic issues	• Develop methodology for the application of risk analysis in the water industry. (2.27)
Climatic Change	• Evaluate the need for new research on the implications of climatic change for the hydrological cycle and water management (3.6)
Freshwaters	• Continue basic research on hydrological and hydraulic processes for the purposes of predicting run-off and recharge to groundwater (3.7), sediment transport and effects of sub-surface flow on water quality (3.8)
	• Investigate occurrence, causes and effects of contamination of groundwaters by trace organic substances (3.12)
Marine Environment	• Develop understanding of the processes determining water quality and simulation models to predict the response of marine ecological systems to pollutant inputs (3.21)
Sludge Disposal to Sea	• Assess the costs and feasibility of establishing an integrated field and laboratory based programme of work to evaluate new approaches for measuring the effects of sewage and sludge disposal to sea (3.32)
Agriculture, Forestry and other Land Uses	• Evaluate water quality and other implications of changing agricultural practices including cropping patterns (4.5), fertiliser usage (4.6), pesticides (4.7), animal slurry (4.9), silage (4.10), and irrigation (4.12).

Waste disposal on Land	. Further study of the effects of sludge disposal on soil fertility and the long term implications of sludge disposal to land (4.37)
Monitoring and Collation of Data	. A long term and multi-disciplinary programme to develop understanding of how organisms respond to their physical and chemical environments and how organisms are inter-related within their communities (6.5)

6. Engineering and Processes Research

Our major recommendations are:

Water Demand	. Assess the implications of domestic metering and the prospect of controlling demand through tariff structures (5.3).
Water Treatment	. Develop reliable and cheap plant for the removal of nitrate from potable water (5.8)
	. Evaluate alternative methods of disinfection and means of removing mutagenic compounds and their precursors (5.9)
Intake Protection	. Develop effective water quality sensors using biological and physical/chemical sensing systems and application of risk analysis to operational procedures for handling pollution incidents and the design of works (5.11)
Sewage, Trade Effluent and Sludge Processing	. Study the implications of stimulating the development of British pollution control equipment and instrumentation (4.34, 5.13)
	. Explore the possibilities of collaboration between the water industry and universities on the application of advanced biotechnology to sewage and sludge treatment (5.14)

- Expand existing research on the reduction of toxic metals and persistent organics in sewage sludge (5.15)

Underground Services

- Develop understanding of the effects of traffic loading on water mains and sewers (5.10)

- Monitor progress on development of trenchless pipelaying techniques and consider a financial contribution to development costs (5.10).

7. Future Activities

We do not recommend the continued existence of our Committee. We do consider, however, that some forum for continued surveillance of long term research strategies in this broad field is necessary in addition to the existing machinery for research formulation. **We recommend that a small working group, chaired by the Chief Scientist, DOE, is established to facilitate and monitor implementation of our recommendations as described in Chapter 8.**

CHAPTER 1 INTRODUCTION AND APPROACH

Terms of Reference

1.1 The Report on the Water Industry by the House of Lords Select Committee on Science and Technology (Session 1982-83, 1st Report) recommended that:

> 'DOE should assume responsibility for ensuring the existence of a long-term research strategy in the Water Industry, which takes into account the needs of that industry and of other interests affected by the industry's activities'.

1.2 Evidence to the Select Committee suggested that strategic research, defined as "long-term investigations of perceived problems", was at risk of being neglected. The Select Committee felt that only the Department of the Environment could take on this strategic planning function and ensure that views from outside the water industry are adequately represented.

1.3 After consultation with interested parties and with the approval of Ministers our Committee was appointed, with the following terms of reference:

> "to report to the Secretary of State on the need for research relevant to (a) the longer term issues and opportunities for the water authorities and other water undertakers, and (b) other longer term problems of water policy including those relating to water conservation, the aquatic environment and public health; and having regard to current research programmes, to advise on any gaps that need to be filled and how long term problems and opportunities should be addressed in the future".

1.4 The membership of the Committee covered a broad spectrum of experience in industry, the sciences and Government. A list is at Annex A.

Definition of the Problem

1.5 We have examined the need for 'long term investigations of perceived problems'. Our terms of reference go rather wider than those implicit in the original Select Committee Report, in covering not only the water industry but longer term problems of water policy generally. Consequently, we have found it necessary to review the environmental, social and economic context within which Government policies for water are formulated and the industry operates. We have looked first at the likely needs for research to provide a basis for the development of policy. Against this

background we have formed a judgement of the adequacy of current research on long term issues, and of the most important gaps.

1.6 We have not sought to define 'longer term' in any absolute way. The speed of development varies widely across the issues we have examined and a rigid timescale of years would have constrained rather than aided our work. Instead, we have regarded an issue as 'longer term' if it extends beyond the immediate concerns of Government and the industry, yet clearly poses problems against which we may be fore-armed by research now. We have similarly used the term 'research' in a broad way to cover the process of acquiring, analysing and interpreting information to address long term problems and also to cover the development of processes and techniques.

1.7 The term 'water industry' is used frequently in this report. Like the House of Lords Select Committee we have taken it to encompass the statutory water undertakers, together with research organisations, consulting engineers, contractors and manufacturers who support them. In addition, in certain contexts it is appropriate to include in this definition Government Departments with statutory responsibility for water matters including DOE, Ministry of Agriculture, Fisheries and Food (MAFF), Welsh Office (WO), Scottish Development Department (SDD) and Department of Agriculture and Fisheries for Scotland (DAFS).

1.8 The Government is responsible for laying down, by statute and regulation the way in which rivers, lakes, groundwater, estuaries and coastal seas in the United Kingdom are managed and used. In England and Wales ten water authorities are responsible for the provision of all water services in their regions - water resource development, water supply (in association sometimes with water companies), sewerage (sometimes through the agency of local authorities) and sewage disposal, river conservation, pollution control, land drainage and sea defence, fisheries, and some navigation and water based recreation. The water authorities thus combine a service of supply and treatment with a wider function of environmental protection. In Scotland, water and sewerage services are the responsibility of the regional and islands councils, who also have permissive powers in relation to sea defence and protection of non-agricultural land against flooding, while pollution control is exercised by the river purification authorities.

The Approach to the Task

1.9 We met first on 9 May 1984 and completed our work at our 8th meeting on 19 December 1985. This report has been constructed following a framework agreed at our third meeting. Individual committee members, Departments and the Secretariat have

provided working papers on particular issues and we have also taken note of the findings of a number of expert committees and study groups. We have attempted to form a view of all the relevant issues without repeating the work of such groups. The committee is indebted to the many organisations and individuals who have put forward their views on research requirements and supplied details of current programmes.

1.10 We structured our analysis around four main themes:

- the social and political trends affecting the functions and performance which the community requires from the water industry;

- the environmental context within which the industry must operate;

- external industrial and technological factors affecting water demand and water quality;

- technological developments which may affect the way in which the industry discharges its functions.

1.11 It is a common defect of studies like ours that they assemble a massive catalogue of desirable research but fail in the far harder task of indicating the subjects that are truly of first importance. We have been conscious of this danger since the broad sweep of our survey could well have left us in such a situation. Our response has been to take three successive steps:

a. to review broad fields of need and knowledge;

b. to identify gaps in current or planned activities, and areas which, while covered by some research, appear to receive inadequate effort;

c. to suggest priorities.

1.12 Chapters 2-5 describe the finding of this analysis. Chapter 6 then looks briefly at the need for development of monitoring methodology and data bases.

1.13 The recommendations of our report are tabulated in Chapter 7 under the headings Environmental Research, and Engineering and Processes Research.

1.14 Finally, we have briefly examined the organisation of water research in the UK and concluded with our recommendations on the necessary arrangements to ensure continuing attention to longer term needs.

CHAPTER 2 SOCIAL AND POLITICAL TRENDS AFFECTING DEMANDS ON THE WATER INDUSTRY

2.1 Demands made on the water industry by the wider community are a fundamental driving force behind many of the technological developments discussed elsewhere in this report. They also exert great influence on the development of water policy, the allocation of statutory responsibilities, and the setting of standards and objectives.

2.2 The social context within which the industry operates has changed significantly in recent years. The conservation of natural beauty and amenity, and the provision of facilities for recreation have grown in importance. Higher standards of pollution prevention are being demanded throughout the European Community. At the same time there have been increasing demands for cost reduction. We have no way of predicting precisely how these social demands will develop over the coming decades, but we expect that pressure for stricter standards of health protection and environmental quality will be maintained. We foresee a possible conflict of interest between the commercial and regulatory roles of the water industry, the former being connected with the supply of clean water and the treatment of water at least cost, and the latter with achieving standards of quality not necessarily directly beneficial to those on whom the charges primarily fall. We consider that research can make a major contribution to the resolution of conflicting demands and the achievement of rational policies.

2.3 We are aware that there are other influences at work, and a topical example is the current proposals for the privatisation of water services in England and Wales. Although this might have consequences for research the timing of our inquiry has prevented us from detailed analysis. However, we do not believe that our fundamental conclusions concerning environmental or engineering research requirements would be changed by a consideration of this subject.

Environmental Protection

2.4 The background to our consideration is the radical change in attitudes towards environmental protection in recent years. The historical emphasis was on remedying obvious acute damage or risk to the environment or to human health. The control measures usually lay very much within the power of an individual Government, local authority or public regulatory authority. Now the emphasis has turned more to concern about the suggested insidious effects of long term exposure to chemical or physical agents at very low concentrations, and also to the international dimension of problems.

2.5 It is unlikely that this trend will be reversed. Another trend, which may also persist, is leading from remedial towards precautionary action. In consequence, investment is likely to be demanded not only to rectify proven or probable damage attributable to obvious cause, but also to counter possible or even remotely possible risk. This in turn will inevitably lead to substantial argument at national and international level about relative risks, costs and benefits.

2.6 So far, DOE and the water industry have stressed the importance of setting environmental quality objectives (EQOs) and standards (EQSs) which define goals and maximum allowable concentrations in the environment. These values have been derived from a consideration of the use to be made of the waters in question, the damage likely to result from particular levels of discharge, and the costs of the measures necessary to secure a range of alternative concentrations. It is also possible, in setting EQSs, to take account of the fact that many of the by-products of human activity that find their way into the aquatic environment occur there naturally, and that the living systems have already adapted to them. This is true of substances such as nitrate and phosphate, radionuclides and heavy metals - some of which are essential for life either as nutrients or trace elements.

2.7 The EQO/EQS approach has the merit of flexibility, and is cost-effective because it allows the dispersive capacity of a water body to be used so long as it is not mis-used in a damaging way. In contrast, the precautionary approach argues that discharges of the most hazardous substances must be minimised, using the best available or best practicable technology. Both approaches are permitted under current European legislation, and they are certainly not mutually exclusive. **We recommend study of the merits and investment implications of combining an EQO/EQS approach with emission limits for "black list" materials.**

2.8 The EQO approach to pollution control requires knowledge of transport and transformation of pollutants in the environment, incorporation in sediment, remobilisation, bioaccumulation and other processes. Considerable research effort has been devoted to understanding dispersion and neutralisation mechanisms and to the development of predictive models; good progress has been made. However, more needs to be done, especially in view of the continuing pressure for higher environmental quality and the need to judge the cost-effectiveness of new technology. **We believe that it is a matter of highest priority to sustain our considerable national capacity in these fields, and to develop methodology that will allow the ecological, technological and economic data to be brought together for modelling purposes and the derivation of appropriate control policies.**

2.9 We appreciate that for substances of high proven toxicity, there will be pressures to eliminate concentrations in water bodies especially in situations where cumulative or long term effects are possible. These pressures are understandably greatest where there is uncertainty. Since absolute elimination is virtually impossible, we believe that research into dose - effect relationships for such substances, and into ecotoxicology (discussed below) remains essential if sound decisions about tolerable concentrations and necessary safety margins are to be made.

2.10 It has been estimated that some 15-20 organic compounds enter bulk manufacture each year within the United Kingdom, and their residues and degraded products will, in most cases, be found in water bodies. It would be prohibitively expensive, as well as inefficient, to pursue programmes of empirical dose-response testing of each such compound, or combinations of the much larger number of compounds already in use, for each of the many species, that could be affected by them. The Committee believes that it would be cheaper and more efficient to study how particular vital metabolic processes of selected organisms are affected by active toxic stimuli at the molecular level. Knowledge of how particular processes are inhibited will thus point to those organisms which are especially susceptible to damage. **For these reasons we support the expansion of basic research on the physiological and biochemical bases of toxicity in aquatic organisms.**

2.11 Changes within the aquatic environment, the ways in which these changes can be detected, the ways in which their future development can be forecast, and the ways in which their more serious consequences can be alleviated, are all legitimate areas for research which cannot be properly explored solely by laboratory studies. The Committee has identified the need to continue research into relevant basic biology (reproduction, range of habitats, growth, energetics) of the organisms inhabiting both clean and polluted rivers, lakes, estuaries and coastal seas, so that those organisms that are particularly at risk - or which on the other hand, have the potential to become an environmental nuisance or hazard to health - can be identified and subsequently monitored. The difficulties inherent in detecting and identifying ecological fluctuations caused by low level chronic effects of pollution must, however, be borne in mind.

2.12 The doctrine of best practicable environmental option for the disposal of waste is likely to be an increasing feature of the scene. It implies that the potential risk associated with the disposal of a waste has to be judged against all the alternative disposal pathways, and that sectors of the environment, or the responsibilities of particular types of authority must not be regarded as

self-contained. This in turn implies that where there is an option for disposal of a waste by dispersion in the freshwater or marine environment, by concentration and disposal on land or by incineration and dispersion in the air, the alternative risks, costs and benefits will need to be weighed. We do not know enough about the factors governing the movement of substances through geological strata, the aquatic environment and ecological systems to make reliable assessments of this kind. A proposal now before the Council of the European Communities calls for a progressive reduction in the dumping of sewage sludge and other substances at sea and a judgement of the acceptability of such a policy would depend on an analysis of the environmental implications of alternatives. **We consider that the best practicable environmental option for the disposal of wastes cannot be stated without more research on the properties and environmental pathways of their constituents and on the cost of alternatives.**

Drinking Water Quality and Health

2.13 It is unlikely that there will be slackening of concern over the human health implications of low level constituents of potable water supplies. Recent decades have seen the adoption of increasingly stringent quality criteria for many substances present in drinking water. Partly as a consequence of the considerable developments in the methods for analysing water, attention has turned from the established control of well-defined hazards to the investigation and assessment of potential hazards from chemicals and, to a lesser extent micro-organisms. The level of concern remains undiminished in spite of the lack of any firm evidence that potable water which conforms to the currently accepted chemical and microbiological standards is hazardous to human health. Given the importance of health related issues and the implications for the industry, we accept that there is a need to advance our understanding of the science and to undertake precautionary research.

2.14 By 1981 over 300 volatile organic compounds had been detected in samples of potable water taken from United Kingdom sources (1). Further examination, aided by advances in analytical chemistry have added many more volatile and non-volatile organics to the list. We note that work continues on the identification of chemicals in water, including the non-volatile organics. There is also considerable research on chemical interactions in water, and the effects of water treatment on the chemicals in the source water. Rather less attention has been paid to the effect of the distribution system on the chemical quality of water in supply. This is an area which is likely to assume greater importance as old distribution systems are renovated or replaced and new techniques and new materials of construction are introduced. **The Committee recognises the importance of these areas of activity and supports the continuation of research on them.**

2.15 The study of the inorganic constituents of potable water is older than the advances in identification of the organic constituents. Quality criteria for many inorganic substances have existed for many years, and are often based on well-established data on toxicity. Gaps still remain, however, in our fundamental knowledge - for example, **little is known of the distribution of trace metals and metalloids between the various forms in which they can exist in water ('speciation').**

2.16 Estimates of human exposure are usually based on the calculated oral intake of water or water-based beverages. **In the longer term more information will be required on other forms of exposure (eg percutaneous, inhalation of water vapour or aerosol, or via water used for cooking)** if it becomes necessary to assess more accurately the intake of potentially hazardous substances. Methods for investigating these other routes of exposure are poorly-developed, but at present are not of great importance, given the considerable uncertainties inherent in the evaluation of the significance to health even when exposure data are reliable.

2.17 Knowledge of the toxicity of many of the identified compounds is scant. Although almost all of them are present at minute concentrations and may be of no consequence to human health, a proper assessment of hazard is not possible unless adequate tests have been performed in a range of well validated biological systems. New test systems are being developed and validated, and should help to provide a broader basis for assessment; but such basic research has implications in many fields, and is not primarily the responsibility of the water industry. There is already a considerable body of research on the effects of concentrated extracts of drinking water in mutagenicity tests. The future direction of this research, and its implications for water treatment, are under consideration by DOE and DHSS in conjunction with expert medical advisory committees. **We see a need for continuing work in this area.**

2.18 Where there is adequate reason to suspect a health hazard from a constituent (or a mixture of constituents) of water, it may be possible to undertake suitable epidemiological studies. Unfortunately, since low exposures may produce only small effects, failure to detect an effect cannot provide complete reassurance. On the other hand, the discovery of an association is not of itself proof of cause and effect, and interpretation must take all the available evidence into account. Where a named chemical is being assessed it may be necessary to direct such studies to groups which are considered to be especially sensitive to the chemical in question (for instance, children, the aged, people with specific allergies or other disease states) or to people with unusually high exposures (eg haemodialysis patients, occupational groups). There have already been many epidemiological studies in several areas of

concern about potable water quality (eg. nitrate, asbestos, hardness, fluoride, chlorination by products), and further studies of this nature are in progress. The Committee has not identified any immediate deficiencies which could be remedied by feasible epidemiological investigations in the UK.

2.19 The effects (if any) of long term ingestion of the low concentrations of chemicals found in potable water are likely to be manifested as chronic diseases. Despite considerable research into certain chronic disease (cancer, common cardiovascular diseases) the mechanisms underlying even well-established links in animals or humans between them and specific chemicals are unclear. **Progress in the interpretation of toxicological data will therefore depend crucially on advances in the basic medical sciences,** the conduct and significance of which extend far beyond the boundaries of water research.

2.20 It is known that water which has been adequately disinfected, as judged by standard methods using bacteria as indicator organisms, may still contain viruses. It has not been shown that humans can be infected as a result, **but there is a need for a fuller examination of the effects of water treatment processes on rotaviruses and other potential human pathogens, both viral and protozoan (eg Giardia).** Examination of water for viruses is at present expensive and slow; **the development of rapid and efficient methods suitable for virological testing would advance our understanding of the fate of viruses in water.** Although the use of bacterial indicator organisms has been successful in ensuring the microbiological quality of potable water, continuing assessment of the adequacy of these organisms as indicators, **and validation of the technical methods used to determine microbiological quality, is necessary.**

Amenity, Conservation and Recreation

2.21 We expect the trend towards higher environmental quality goals to extend beyond increasingly stringent water quality criteria. For instance, there is already a demand for a new balance between the drainage and conservation of wetlands, especially those providing distinctive landscapes or wildlife habitats. The Nature Conservancy Council (NCC) and the Countryside Commission have expressed concern over the loss of wetlands in lowland Britain. In contrast, new wildlife habitats and amenities have been created by the sensitive re-development of old gravel workings. We believe this is not an area where policy is being inhibited by lack of research but we accept the need for the continued monitoring of trends. We note that both the NCC and the DOE have research programmes designed to record the rate of alteration of major countryside features, and we urge that as far as wetlands and freshwaters are

concerned, there is proper discussion with water authorities over the results and their implications. **We also consider that water authorities should discuss with MAFF, the NCC and the Countryside Commission the advantages of new design and management of drainage schemes so as to protect important wetlands, grazing marshes and water meadows and this may show a need for research.**

2.22 We note also the considerable interest in recreational fishing which is said to be our largest popular sport, attracting over 2 million people. More broadly there is a continuing increase in the popularity of water based sports of all types. Under the Water Act 1973 in England and Wales "water authorities may take steps to secure the use of water and land associated with water for the purposes of recreation and it shall be a duty for all such undertakers to take such steps as are reasonably practicable for putting their rights to the use of water and of any land associated with water to the best use for those purposes". The Countryside (Scotland) Act 1967 gives Scottish water authorities powers to provide recreational facilities for the public. Other Acts relate specifically to fisheries responsibilities. The duties carry implications for research into the ecological consequences of water storage and transfer, river regulation and land drainage and the means of achieving a satisfactory balance between conflicting interests.

2.23 In parallel, the Sports Council has a function to promote sport and recreation and co-operates with the Countryside Commission in England and Wales in Regional Councils for Sport and Recreation. Ministers have recently announced the results of a review of the functions of these Regional Councils, and have stated that they will remain forums in which interests of conservation and recreation can be reconciled. We consider that this is important for water sports. The Sports Council inform us that present research is inadequate as a foundation for forecasting future demand for boating or angling, and that work is also needed on the economic processes and management systems which can best match supply to demand. **We note this and suggest that since the water authorities are also members of the Regional Councils for Sport and Recreation these matters are discussed further there and, if necessary, carried forward within the Sports Council's own research programmes.**

Efficiency and Economy

2.24 The aim of the water industry is to meet the required standard of service with efficiency and this lies behind much of the research funded or carried out by water undertakers. The contribution of new technology to efficiency will, in our view, be of increasing importance and we return to this theme in Chapter 5.

2.25 There are three aspects of the social context which require further examination, and they extend beyond the traditional technical and scientific boundaries of water research. They all concern the need to reduce the area of subjectivity in policy formulation and management and we consider that research on each of these is urgent for Government and the industry itself.

2.26 First, we do not feel that reliable methods exist to define community attitudes. We accept that market survey techniques can be used to measure consumer views on specific standards of service provided by water undertakers, such as the colour, pressure and reliability of water supplies. We also acknowledge the role of consumer consultation exercises in formulating regional investment proposals. Public opinion polls have also been used as broad indicators of concern for the environment. However, we consider that such polls are of only limited use if they fail to present the economic consequences of alternative actions. It is important to force the respondent to consider the hard choices of the real world. **We believe that research into the development of methods for quantifying public attitudes on environmental matters would be worthwhile.** Reliable methods would be useful aids in the development and justification of environmental policy and we note the contribution that the Office of Population Censuses and Surveys might make to such development.

2.27 Secondly, we consider that there is considerable scope for the application of the developing technique of risk analysis in the water industry. The techniques have potential application to the quality of potable water supplies, pollution prevention and reservoir safety, on which we know that some work has begun. A comparative evaluation of the risks associated with the water industry's procedures and practices and those of other man-made and natural hazards would considerably assist decisions on priorities for action - although it does not follow that remedial action should strictly follow the sequence of objectively assessed risk, when public preference points in other directions. **We recommend methods for applying risk analysis in the water industry be developed.**

2.28 Thirdly, there is at present no accepted method of defining environmental benefit in financial terms and this limits the use of traditional cost:benefit analysis in the environmental field. It is also very difficult to identify a consumer group for clean rivers or for an aesthetically attractive aquatic environment. It is therefore only possible to make subjective judgements about, for example, the environmental quality objectives for many waters, the priority for conservation activities or the standards of flood protection in some areas. **Research is necessary to produce a generally accepted method for evaluating environmental benefit.**

The Export Market

2.29 Our terms of reference require us to advise on research relevant to the future opportunities available to the water industry and we regard such opportunities as including the export of goods and services. Much of the work of the private sector of the industry is vested in such activity and many water authorities are becoming increasingly engaged in providing services abroad. Many of the technical difficulties of water management overseas are similar to those encountered in UK and thus much of the long term research that we advocate for the solution of problems in UK should have export applications.

2.30 We have considered whether, in addition to such work, there is a need for long term research directed specifically at problems encountered in overseas markets but not in UK. Environmental and social conditions do create distinctive problems, such as those arising from regional geology, climate, soil, agricultural practices, water chemistry, social traditions, infrastructure and the nature of the social resources available. However, we feel that the research requirements are more tactical than strategic and that those seeking work abroad cannot escape the need for site-specific investigations for each particular project.

2.31 The principal need is the ability to commission appropriate UK research organisations to investigate specific practical problems on repayment terms without excessive delay. Many such UK organisations are becoming increasingly commercially oriented and willing to undertake such work; nevertheless it will be possible to cater for future needs adequately only if both 'supporting' research continues and if resources can readily be reallocated as demands change.

CHAPTER 3 THE ENVIRONMENTAL CONTEXT WITHIN WHICH THE INDUSTRY OPERATES

3.1 Our second broad theme concerns changes in the environmental context within which the water industry operates. Our examination covers the implications of long term environmental changes arising naturally and from human influence, the environmental impact of the water industry's activities and the extent of our knowledge of the natural processes which may be affected.

3.2 The areas which we have reviewed are:

- climatic change
- factors affecting the flow, composition and ecology of fresh waters
- factors affecting the composition and ecology of estuarine and coastal waters.

Climatic Change

3.3 The increasing levels of atmospheric carbon dioxide, arising principally from the combustion of fossil fuels, and other gases such as methane, chlorofluorocarbons and nitrous oxide, are causing widespread concern amongst scientists. It is expected that carbon dioxide levels will double over the next 70-100 years and lead to higher global surface temperatures. Increasing quantities of other "greenhouse gases" may accentuate the effect. An increase in average global surface temperature of 2-5°C, with a maximum of 8°C in high latitudes, has been predicted by some general circulation models. Such temperature changes would be associated with very significantly changed weather patterns, including changes in the frequency of extreme events. Some projections imply that melting of polar ice might raise world sea levels by 0.5 to 0.75 m within the next century. These changes would have considerable implications for the water industry and we consider it essential to keep abreast of research in this area.

3.4 The Committee takes the view that the extensive international activity in the development of climatic models is adequate. This work should lead to improvements in the reliability of predictions. However, the Committee is convinced that more research will be necessary to establish the consequences of possible changes in climate and weather patterns, and the responses of biological systems. Such knowledge is of fundamental importance to the planning and operation of water resource systems and flood protection and coastal works.

3.5 We recognise that the water industry is aware of these problems. The Water Authorities Association Technical Group has recommended the examination of rainfall data to evaluate any change in variability. They also recommended that the Institute of Oceanographic Sciences examine data on changes in the frequency and magnitude of tidal surges and trends in mean sea level.

3.6 These evaluations need to be more closely related to the studies and reviews the Meteorological Office is conducting and we suggest that it would be timely for the latest scientific evidence on likely climatic change to be discussed by the Meteorological Office, NERC, DOE and the water industry. Following this discussion, **we consider that those concerned should evaluate the urgency of new research on the implications of such change for the hydrological cycle and water management.** These matters must be kept under regular review as the present national and international effort on the development of climatic models proceeds.

Flow, Ecology and Composition of Fresh Waters

3.7 **Hydrology and hydraulics.** The physical principles of the component processes whereby the precipitation falling on a catchment is transformed into river flow are reasonably well understood; some difficulties remain however, when models of these component processes are put together for the purpose of predicting storm run-off or recharge to groundwater. Two particular sources of difficulty are: the extreme heterogeneity in the hydraulic characteristics of adjacent and apparently similar areas of soil and vegetation; and the wide differences in time-scale at which hydrological processes act, causing computational problems. **We recommend continued research to resolve these difficulties.**

3.8 Although there is a reasonable basis of knowledge concerning the hydrological processes that govern the quantities of water retained in storage within a catchment and flowing from it, the processes that control the chemical composition of water through its interactions with vegetation, soil, rock, river bed and suspended material are far less well understood. **Research is needed on:**

a. **interception and snowmelt:** whilst the magnitude of snowmelt and water losses, caused by the interception of precipitation by plant canopies, are well documented, more needs to be known about the manner in which evaporation and melting of snow control the pathways taken by pollutants deposited from the atmosphere;

b. **flow through soil and rock:** the mechanisms whereby water flows through heterogeneous soil and rock, and at the same time interacts with these matrices thereby affecting the chemical composition of both water and matrix, remain poorly understood. In particular, the flow of groundwater between geological strata is important to both qualitative and quantitative aspects of aquifer development and requires further research;

c. **sediment transport:** the scale of wind and water borne soil loss in Britain requires clarification. Research is also needed to determine how the clear-felling of timber stands affects the release of sediment and bed-load material from hill-slopes. Large releases of sediment lead to a loss of upland reservoir capacity and major changes in upland water quality, and also have deleterious effects on the spawning of salmonid fish. We consider it important that the gravity of such problems is evaluated more precisely in this country.

3.9 **Land drainage, flood protection and coastal works.** The final and detailed conclusions of MAFF's Flood Protection R&D Committee are not available to us. However, we are aware of the general thrust of their deliberations and have used them in our consideration of the longer term research needs. There are two broad areas which we consider require greater emphasis. **First there is a need to develop engineering solutions to land drainage and flooding problems which are more in sympathy with the natural environment.** This will require study of aspects such as comparisons of artificial and natural means of river and coastal bank protection and the recovery of habitats after engineering works should be the subject of the discussions we have advocated in 2.21.

3.10 Secondly, there is a need to bring into the economic appraisal of schemes some quantification of the currently intangible benefits and disbenefits so as to allow a better balance between functional requirements and the interests of conservation and amenity. We have already recognised (in 2.28) the need to develop methods of defining environmental benefit in financial terms and, **we recommend that further consideration is given to the detailed research requirements.**

3.11 **Groundwater quality.** Groundwaters, which provide about one third of potable supplies, have traditionally been thought to require only minimal treatment before supply, for example simple disinfection and perhaps removal of iron and manganese to avoid problems of discoloration. There is currently considerable interest in the nitrate concentrations of surface and ground waters especially in parts of eastern England where levels have been rising in recent decades. Nitrate concentrations in some supplies currently exceed, or are likely shortly to exceed, World Health

Organisation (WHO) Guidelines and EC standards. In implementing the EC Directive on Quality of Water for Human Consumption and after taking medical advice, the Government has decided to permit the continued use of supplies with nitrate concentrations up to 100 mg/l (with 3 monthly average concentrations not exceeding 80 mg/l). While at present this means that remedial action is required for only a small number of supplies, it is predicted that continuing increases of nitrate will necessitate blending with low nitrate water, water treatment or commissioning of new supplies - all at considerable cost. The necessary treatment technology is available but as noted in paragraph 5.8 further research to improve cost effectiveness is required. Nitrate problems and the activities of the Nitrate Coordination Group are discussed further in Chapter 4.

3.12 There is also evidence of contamination of groundwater by trace organic substances, for example hydrocarbons from fuels and lubricants, pesticide residues and metabolites and phenolic substances from spillages or waste disposal. The concentrations of these contaminants are generally low, usually at least one order of magnitude less than in surface waters but the potential for progressive accumulation is a matter of concern. A problem peculiar to groundwaters is posed by the chlorinated hydrocarbons used as solvents and for cleaning and degreasing. These exchange freely with the atmosphere when occurring in surface waters but may accumulate to significant levels in groundwaters. Recent preliminary work commissioned by DOE (3) shows that, near to urban or industrial areas, groundwaters may contain concentrations of dichloroethene, trichloroethene and tetrachloroethene greater than the guideline values suggested by WHO. The significance of such concentrations is difficult to determine, and is under consideration by expert advisors to the Government. **We recommend further investigation of the occurrence, causes and effects of contamination of groundwater as a matter of high priority,** and the development of specific treatments for groundwaters used for potable supplies may become necessary.

3.13 **Eutrophication in fresh waters.** Eutrophication (over-enrichment with nutrients leading to excessive plant growth) is a widely publicised consequence of pollution. It is not a serious problem for water supplies in the UK, although it can be a nuisance in amenity and recreational waters and in some areas with fish farms (see 4.17-4.22). There is now a good understanding of the mechanisms which lead to it in UK freshwater environments. There is also a good basis of knowledge to permit control of the succession of algal species that occur through the year within lakes and reservoirs. **However, there are no economic methods at present for the control of eutrophication in amenity waters and below fish farms and we see scope for research and development in this area.** Eutrophication processes in other regions of the world

are less well understood and further research is required in support of consultants active overseas, particularly in the tropics. (See 3.25 for eutrophication in coastal waters.)

3.14 **Acidification** . There is substantial national and international research effort on the processes of formation, transfer and deposition of acids (notably sulphuric and nitric) derived from the sulphur and nitrogen oxides produced in fuel combustion. In Britain, rainfall acidity has been surveyed by the Warren Spring Laboratory (4) and NERC. The acidity of surface and ground waters is largely dependent on the extent and nature of interactions between deposited acid and vegetation, soil, drift deposit and bedrock, together with the acid neutralising capacity of the recipient waters. All these interactions are the subject of research supported by DOE, SDD, NERC, the water authorities, the Central Electricity Generating Board, the National Coal Board and the universities.

3.15 The extent of surface and ground water acidification in the UK is being assessed by the UK Acid Waters Review Group (UKAWRG). Although the evidence examined by the UKAWRG does not indicate the extensive occurrence of surface water acidification, local evidence of acidification was identified in certain distinct geological regions. Further evidence linking afforestation of susceptible catchments with the occurrence of increasingly acid runoff has also been identified.

3.16 We understand that the UKAWRG is to publish an interim report shortly and this will include some recommendations with respect to monitoring. It will address research needs during the next phase of its work and these will be identified in its final report. **We welcome the work of the group and recommend that its proposals for further, more substantive, investigations are given close consideration when they are made.**

3.17 **Freshwater fisheries management.** Salmon and freshwater fish are a valuable natural resource in the UK, providing a basis for extensive recreational fishing, and to a lesser extent commercial food fisheries and fish farming. Currently, relevant R&D in the UK is undertaken by MAFF, DAFS, NERC, WRC, water authorities, river purification boards (RPBs) and universities, and this divided responsibility may account for a certain lack of cohesion and impetus in research. However, the MAFF/WAA Fisheries Technical Liaison Committee has now been established to provide a forum for discussion and collaboration on technical aspects of fisheries research and development in England, Wales and Northern Ireland. We support the aims of FTLC and trust that progress will be made to meet the long recognised fisheries research needs.

3.18 There are two broad categories for longer term research; developing understanding of salmonid and coarse fisheries as a basis for management of the resource; and assessing the impact of environmental changes. Long-term investigations are essential since an understanding of the resources cannot be properly obtained without knowledge of the generation-to-generation fluctuations within natural fish populations. **In the first category we recommend further research on -**

Natural population control processes in mixed-species communities;
Scope for stock enhancement by habitat engineering and restocking;
Improved methods for studying fish populations in large rivers;
Advances in the science of social and economic evaluation of freshwater fisheries in order to optimise benefits.

In the second category we recommend research into -

Effects of river flow manipulation and other water resource engineering schemes on fisheries;
Effects of agriculture, land drainage and channelization;
Pollution, especially episodic pollution;
Fish farm effluents.

3.19 **We also recommend research to determine the extent to which the European Inland Fisheries Advisory Committee (EIFAC) tentative water quality standards** for coarse fish can be exceeded and still allow the existence of a limited fishery. We do so because for fisheries undergoing restoration the imposition of too stringent a standard may involve excessive expenditure.

3.20 The growing significance of angling as a leisure activity has already been referred to in 2.22. It brings with it consequential problems which have only recently been appreciated, notably the impact of anglers and angling not only on the fish resource but on the associated wildlife and habitats of the river corridors and lake margins. **We recommend further research to develop our understanding of these impacts** such as, for example, the harm to swans and other water birds from lead shot.

Composition and Ecology of Coastal and Estuarine Waters

3.21 **Coastal and estuarial water quality.** Our primary task should be to develop an understanding of the processes determining the quality of coastal and estuarine waters. This will then allow predictions to be made about responses of organisms to

pollution and other impacts. Such an approach will require analyses based on sound laboratory experimentation leading in turn to the development of simulation models. Similar models are desirable for the inputs of metals, liquid nutrient effluents and persistent toxic chemicals. **We consider that continued work in this field is urgent and is inseparable from the development of long term field observation and experimentation.**

3.22 Research requirements have been examined in detail by the Coasts and Estuaries Research Review Group (CERRG). The Group, now disbanded, concluded that central government should fund more process orientated investigations, and that more encouragement should be given to multi-disciplinary research, particularly when this was supported by predictive modelling and was likely to be applicable in different places. The Group made a number of recommendations for physical, chemical and biological research to support monitoring in coastal and estuarine waters. These included the need for a better understanding in estuaries of:

a. the physical transport processes - fluxes and budgets of water, sediments and associated contaminants, particularly across the salt water/fresh water interface, where complex physical, biological and geochemical interactions occur which control net input of contaminants to marine waters,

b. the chemical fluxes associated with the interaction between suspended particles and water along salinity gradients;

c. chemical and biological interactive processes occurring in settled sediments; and

d. the exchange of material between settled sediments and the water column, and the role of sediments as a sink for pollutants especially in estuaries.

3.23 Biological research recommended by CERRG included:

a. further work into fundamental processes in toxicology;

b. the role of micro-organisms in affecting water quality;

c. better understanding of contaminant uptake into commercial species - with emphasis on the influence of the chemical speciation of the contaminant on bioaccumulation and interactive effects between contaminants.

3.24 **The Committee supports the conclusions of CERRG and is pleased to see progress on implementing their recommendations.** Of the above topics we attach special importance to:

a. multi-disciplinary studies of the estuarine and in-shore environment, which is both complex and exposed to aquatic pollution; research currently in progress under the aegis of SERC into coastal and estuarine hydraulics, with the aim of improving mathematical modelling of the physical transport processes, is relevant and should be supported and developed;

b. sediments as a sink for pollutants;

c. uptake of pollutants by species of commercial importance.

3.25 The CERRG also concluded that the effects of the increasing influx of nutrients into coastal waters in recent years were imperfectly understood and needed further research. We strongly endorse that conclusion believing that the effects could be of great importance - and not necessarily harmful. The nutrients in question are mainly nitrate and phosphate deriving from agricultural activities and domestic detergents. Since these substances are often in limited supply in the sea their addition enhances natural productivity. Eutrophication has been particularly evident in the Baltic, where it may have caused a dramatic increase in the abundance of several of the major commercial fish stocks in the last decade or so. On the debit side, one consequence of eutrophication in sheltered waters where currents are weak, is that the dead material may sink to the bottom and form a de-oxygenated and lifeless layer. Again, this secondary effect of eutrophication is pronounced in the Baltic but largely absent in the well-mixed North Sea. Additional nutrients are, of course, liable to promote the growth of undesirable algae, certain of which are toxic to fish and man. There are some indications that the occurrence of exceptional algal blooms of this kind has become more frequent in recent years; but this has been noticed in remote areas as well as in those receiving additional nutrients. **These are among the reasons why we consider that the eutrophication of coastal waters and its consequences is a phenomenon which merits close surveillance and a better understanding of the processes involved.**

3.26 **Sludge disposal at sea.** The disposal of sewage sludge is a matter of growing international debate. In view of the heavy cost to the water industry and uncertain feasibility of alternative disposal methods, the Committee made a special study of the present state of knowledge of the effects of sludge dumping in British coastal areas and the long term research requirements. The findings can be summarised as follows-

a. Mass accumulation of organic material occurs at only one site, which is the deepest and least affected by tidal currents. Here the organic enrichment has caused reduced oxygen levels in the sediments over an area of a few square kilometres resulting in very high numbers of opportunistic worms which are able to tolerate these reduced oxygen conditions.

b. Evidence of mass organic enrichment from this and sites in other countries (eg Sweden) is that the effects are strictly localised. In cases where dumping has ceased, the environment and its biota have returned to their former natural state within a small number of years.

c. There is little or no risk to human health from microorganisms present in sludge. If there is a potential route of infection to man it is via contamination of shellfish and this is obviated by locating dump sites well away from areas of shellfish cultivation or exploitation. Current studies have failed to show a relationship between fish diseases and exposure to sludge, but further and more detailed work is required in view of the difficulty of establishing whether or not such causal relationships exist in the marine environment.

d. In a minority of sites the concentration in the local sediments of persistent substances present in sludge, eg heavy metals and synthetic organics, is enhanced. **It is important to know more about the dynamics of uptake and loss of such substances in sediments, and of the partition of the soluble components between sediment and water.** The aim should be to assess the conditions for equilibria, and to identify the ultimate fate of the non-degradable components of sludge, at the various sites.

3.27 We are aware that a considerable amount of long term research is currently progressing on coastal, in-shore benthic, estuarine and open sea populations and communities. Some £1 million per annum is being spent on work associated with licensing sea disposal of wastes, including sludge. This present approach enables the detection of any dramatic changes which may occur in the monitored populations but is less likely to discern subtle long term effects or to identify specific causes.

3.28 The Committee believe that, while ongoing research has already amassed substantial quantities of data and will continue to do so, new studies are required to detect both the changes in flora and fauna in the vicinity of sludge and any more subtle effects on the living systems of the wider sea area surrounding the site which could possibly be caused by the soluble or persistent constituents of sludge. The

major recommendations of our special study concerned the opportunities of new long term surveillance of indicator populations among which plaice, brown shrimp and common mussel are perhaps most promising. However, we stress the importance of establishing the significance of these subtle responses in terms of the underlying natural variability.

3.29 As indicated in 2.10, greater attention should be given to the development of monitoring procedures based on sub-cellular, cellular and physiological responses. Such indications of metabolic stress, if combined with measurement of their consequence to the demographic performance of the population or community in question may offer the prospect of early-warning and diagnostic use. In addition, there is the possibility of agreement on standardising such techniques to provide widely compatible measures of pollution impact. This approach could also have a role to play in the screening of wastes for potentially damaging effects. The drawback of these techniques, however, is their low apparent relevance to the ecologically important measures which may better reflect social concerns (ie measures of ecosystem response at community level) and this forms a challenging area for new research. Consideration should be given to building these techniques into a sustained programme on the demographic performance at population and community level.

3.30 The Committee also recognises the value of small scale experiments in developing pollutant dose - effect relationships. Such experimentation should integrate both laboratory studies and field work (eg transplant experiments with caged mussels). In some countries, Scotland for example, experimental facilities extend to the "mesocosm" level, utilising substantial enclosed areas of marine environment which support reasonably natural communities. Research in these systems can give realistic information about how input chemicals will affect the biochemistry and physiology of organisms. We believe that the responsible research organisations should consider the establishment of further mesocosm studies aimed at a more realistic representation of the natural ecosystem.

3.31 The Committee considers the Liverpool Bay area and the Clyde Estuary to be particularly valuable locations for integrated studies of these new monitoring techniques as they contain relatively "isolated" populations where the performance of successive cohorts can be studied readily. However, we also recognise the need for their evaluation to be carried out in parallel at other important sites such as the Thames Estuary and the proposed new Tees disposal ground. The input of materials to such sites would require monitoring along with the demography of the indicator populations and the contaminant load and physiological responses of individual

indicator organisms. Once started, such research would need to continue over a substantial period of time owing to the difficulties in distinguishing genuine change from natural short term variability without reference to a considerable run of data.

3.32 We are satisfied that this approach to research into the disposal of sewage sludge to sea may have considerable potential. **We recommend assessment of the costs and feasibility of establishing an integrated field and laboratory based programme of work to evaluate new approaches for monitoring the effects of sewage and sludge disposal to the sea.**

3.33 **Sea outfalls and bathing waters** The disposal of sewage through short outfalls to estuaries and coastal waters can lead to offensive conditions and bacterial and viral contamination of the beaches and adjacent water. In 1970, the (Jeger) Working Party on Sewage Disposal recommended that crude sewage should be discharged only after screening and comminution and through diffusers on long outfalls. In 1984, the Royal Commission on Environmental Pollution, in its Tenth Report, endorsed this view. Water authorities are working steadily to remove unsatisfactory outfalls. The principal constraint is the cost of the necessary works. Sea water has a powerful purifying action, and advice given in 1959 is that bathing in water containing sewage which is not visually apparent does not normally present a hazard to health. Where gross contamination does pose a risk, the water is likely to be aesthetically revolting. **This advice should be brought up to date and amplified by an assessment of the effects of freshwater dilution, turbidity and weak sunlight on the purifying action of seawater.**

3.34 The Royal Commission on Environmental Pollution has also commented on the way that the Community Directive on the quality of bathing water (76/160/EEC) has been applied in the United Kingdom. The UK has only identified a few bathing waters and not included a number of the most popular seaside resorts. Water authorities and RPBs have been asked to survey many more bathing waters and compare their water quality with the Directive's standards. We do not recommend any additional initiative in respect of such surveys or monitoring.

3.35 **Shellfish and viruses.** Water and river purification authorities are responsible for the management of those waters that have been designated under the EC Directive on Quality Required of Shellfish Waters. A substantial part of the molluscan shellfish taken for human consumption in this country comes from areas polluted by sewage (there are 62 areas in England and Wales from which molluscs must be be purified or heat treated before sale in accordance with the Public Health (Shellfish

Regulations, 1934). In recent years it has become apparent that one of the major limitations on the safe marketing of such shellfish has been the presence of pathogenic viruses. There is now evidence that molluscs subjected to approved systems of treatment, such as heat treatment or purification in shore-based installations may still cause outbreaks of viral infections. Experience in the United States suggests that these purification systems are inadequate because of the way that the virus particles are held within the tissues of the molluscs. Moreover, while current heat treatment techniques giving only limited heat exposure appear to be inadequate, increasing the heating is not an acceptable solution because it is liable to render the flesh inedible. **Both of these topics are the subject of active research by MAFF and Central Public Health Laboratory, Colindale, and we recommend that this work continues.**

3.36 It is possible that neither of the two studies currently being undertaken will be successful, and an alternative or even complementary option favoured by the shellfish industry, is the removal of the source of pollution - normally a local sewage outfall, releasing treated or raw effluent. In the USA, considerable reliance is placed on chlorination of sewage to ensure that the numbers of faecal organisms in shellfish-growing waters are kept below a level that will render shellfish unacceptable. **We recommend that a systematic study should be made of methods for the removal or reduction of faecal organisms, including viruses, from sewage effluents, of the environmental consequences of using agents such as chlorine and ozone, and of the associated costs.**

CHAPTER 4 EXTERNAL TECHNOLOGICAL FACTORS WITH CONSEQUENCES FOR WATER QUALITY AND QUANTITY

4.1 Our third theme has been to examine industrial and technological developments outside the water industry which may have consequences for water quality and quantity. We have sought to identify trends in industrial activity which may give rise to new or more severe pollution threats or significant changes in the demand for water. Our consideration of the consequential research requirements has covered the need for better means of quantifying these trends as well as the study of their effects.

4.2 We see significant implications for the water industry arising from trends in:-

- agriculture
- forestry
- aquaculture
- gravel extraction from coastal waters
- energy production
- manufacturing industry
- waste disposal on land
- kitchen waste disposal units

We consider below the actual and potential impacts of these activities on the water environment.

Agriculture

4.3 In general, it is not too difficult to predict the significance of changes in agricultural practice for the water industry and for water quality and amenity, once the pattern of such change has been defined. The problem lies in predicting future development in the agricultural industry itself. Yet the water industry must be ready for changes that affect so large a part of its raw material, and may demand substantial adjustments in its regulatory activities. **Accordingly we recommend development of better methodology for forecasting trends in agricultural practices** and we believe that this is a matter for co-operation between the Agricultural and Environment Departments, as part of the machinery now established by their Chief Scientists for exchange and coordination of their research programmes.

4.4 Forecasting trends is particularly difficult at this time when economic forces, public opinion and policy at various levels are all combining to change the course of

agriculture to an extent not experienced since the period of emphasis on expanding production 30-40 years ago. Now the pursuit of greater productivity is being called into question, and concern for the environment is increasing. **Although we accept the difficulties inherent in forecasting the agricultural future, we have considered below some possible agricultural changes with implications for the water industry and identified some aspects which require continued or further research.**

4.5 **Cropping patterns.** Crop production patterns are likely to change in response to changes in agricultural support mechanisms. Lower grade farmland might be turned over to timber production while the better land, much of which is situated over water supply aquifers, might be used even more intensively. Changes in dietary preference may also lead to corresponding agricultural changes. Government as a whole has a considerable interest in evaluating the likely consequences of changes in agricultural support, and we believe that research should include, but will range far more widely than, water quality implications. **The specific question of implications for nitrate contamination should be watched by the Nitrate Co-ordination Group, but the wider issues are for the Agricultural and Environment Departments working in co-operation.**

4.6 **Plant nutrients.** If arable crop production, at least in the most productive areas, were to be increased, some increase in nitrogen input would be probable. Alternative uses for straw, including treatment for use as animal feed or microbial treatment for incorporation in the soil, could also release more nitrate and have consequent water pollution risks. More nitrogenous fertiliser application to grassland has also been forecast for some areas. Nitrate contamination of potable water sources as a result of agricultural activities is already a problem in parts of the UK, principally in East Anglia. There has been considerable research into nitrate contamination and we have a broad understanding of the problem, its links with agriculture and the treatment techniques required to reduce levels to the recommended limits. In their report on the nitrogen cycle the Royal Society (5) thoroughly reviewed existing knowledge and made recommendations for further research. Further developments in agricultural practice and research are kept under close review by the recently formed Nitrate Co-ordination Group which has representation from the water and agricultural interests and whose area of review embraces the developments causing trends, the effects of nitrate in surface, ground and coastal waters and opportunities for control. **We believe that detailed consideration of the longer term research needs should be left to this Group and we recommend that at an early stage the Group should make known its views on the research required to the Chief Scientist, DOE,** for action within the follow up arrangements we propose in chapter 8.

4.7 **Pesticides and herbicides.** One trend which seems likely to continue is the withdrawal of persistent pesticides - especially those liable to accumulate in living organisms - so reducing the chances of long term problems caused by the gradual build-up of concentrations to polluting levels. Pesticides and herbicides have, however, been identified in surface and groundwaters at concentrations exceeding those set as maxima in the EC Directive on Quality of Water intended for Human Consumption. These levels were set when pesticides were more persistent and toxic to animals and may now be inappropriate: the UK is seeking their reconsideration. It is important to note that these substances are not only of agricultural origin but arise from a wide range of industrial activities and also from the control of vegetation on road verges and railway tracks.

4.8 We have taken note of the provisions of the Food and Environment Act (1985) and its measures designed to improve the legislative control of the production and use of pesticides, but we are aware that pollution is most likely to result from a failure to use products in the recommended ways or from carelessness or accidents. The more accurate application of pesticides by controlled drop application and electrostatic spraying could reduce the total amount of pesticide used and, to an even greater extent, the proportion reaching non-target organisms. **In our view it is essential that work should continue into monitoring the spread of persistent pesticides in the environment; that a better assessment of the effects and fate of these substances is made; and that more efficient application methods which will avoid contamination of water courses are devised and used. We believe that effective links should be established between the Advisory Committee structure established under the new Act and the research commissioning machinery of the Agriculture and Environment Departments so that greater prominence is given to environmental issues.**

4.9 **Animal slurry.** Accidental pollution of watercourses by wastes from intensive livestock units is a particular problem for the water industry and in recent years has resulted in a dramatic increase in the number of prosecutions under the Rivers (Prevention of Pollution) Acts. There are, however, several factors which may counter any upsurge in such pollution, including an increasing effort by water and river purification authorities, assisted by their new powers under the Control of Pollution Act Part II. Animal welfare considerations are likely to increase the use of bedding and this may turn farmers away from slurry systems though the change is likely to be slow. Odour nuisance problems may also bring pressures to reduce the use of slurry systems. We do not believe that research by the water industry is required, since the effects of the pollution on watercourses are well understood and the only remedies are abatement at source or avoidance of the problem by adoption of alternative farming practices. We note that Codes of Good Agricultural Practice have

been published by the Agricultural Departments. **However, we do consider that MAFF, the farming community, and the manufacturers of pollution abatement equipment should consider further research.** We have been informed that anaerobic digestion systems, despite their useful production of methane (biogas) are not generally economic under British farming conditions, but we believe that the development of effective treatment systems needs continuing effort.

4.10 **Silage.** Silage making has increased rapidly and the leakage of highly polluting liquid from effluent tanks and the structural failure of silos and associated facilities is now one of the main causes of severe water pollution incidents. This liquor can have a biochemical oxygen demand greater than 80,000 mg/l which is more than 200 times as strong as domestic sewage and is one of the strongest pollutants. Consequently, the discharge from an average silage clamp could completely deoxygenate many miles of all but the largest watercourses. The dry matter content of silage depends crucially on the weather, and the risk of pollution is greatly increased in wet seasons. The problem can be aggravated if attention is not given to reducing the moisture content by wilting the grass before ensiling. **The difficulties are well understood and require no new research by the water industry but, as with slurries, the development of more reliable preventive methods by the farming industry is required** and we commend this to them as important to their future profitability.

4.11 **Biotechnology.** The future application of biotechnology is likely to have a major influence across the whole spectrum of agricultural activity but it is too early to predict the consequences for the water industry. Biotechnology and genetic engineering may provide the means of enhancing biological nitrogen fixation and using fertilisers more efficiently: they may also help waste disposal problems and provide alternative methods of disease and pest control, thus reducing agricultural impacts on the water environment. Equally, certain developments could increase water contamination. **The only practicable course of action is to monitor such developments and their impact carefully.**

4.12 **Irrigation and water demand.** Estimates by the Advisory Council for Agriculture and Horticulture in England and Wales (1980) suggested that irrigation demands would double by 1985 and quadruple by 2000 compared with a 1977 baseline. The figures were regarded as an upper limit and a considerable part of the increase between 1985 and 2000 was for grassland irrigation. In 1984 irrigation demand was below the levels predicted. In many instances the projected demands could not be met by the water industry without substantial investment in river management schemes. **It is accordingly important for the long term planning of water resource development that there is an appreciation of future irrigation demands.** This in turn will obviously

depend on trends in the economy of rural areas. Research in this broad area is being considered by MAFF, DOE and the Economic and Social Research Council (ESRC).

Forestry

4.13 Current Government policies point to increasing afforestation of upland areas and there are also speculations about the replacement of traditional agriculture by forestry in some lowland areas. These trends have implications for water quality, both for supply and as a basis for the ecology of river systems. **It is, therefore, important that we make as realistic an assessment as possible of likely trends, and monitor the actual situation carefully.**

4.14 There is a broad understanding of effects of afforestation on the quantity of water drainage from a catchment. **However we recommend three further areas of research as important for the water industry:**

a. assessment of the seasonal variation in evaporation loss from forests, particularly during summer drought conditions;

b. assessment of evaporation loss at different stages of forest growth;

c. study of the effects of forest drainage practices on the occurrence of floods, periods of low flow and sediment transfer.

4.15 We have already noted the effects of afforestation on the acidity of runoff from upland catchments. **It is also necessary to consider the adequacy of research on other interactions between forestry and water quality,** including the effects of clear-felling of large areas on runoff and the implications of aerial application of fertiliser, lime and pesticides should these practices be contemplated on upland catchments.

4.16 A thorough understanding of all the implications of afforestation for the water industry will permit the additional costs of alternative planting and land management methods or of extra treatment to be calculated. It has been suggested that in some catchments the extra costs likely to be incurred by the water industry will be greater than the value of the timber produced. **This issue clearly requires further exploration, in view of its economic and political implications.**

Aquaculture (including mariculture)

4.17 Some 16,000 tonnes of fish are currently produced from aquaculture and mariculture in the UK each year. Fish farming is expected to maintain a steady growth

over the next 20 years, with production increasing to over 20,000 tonnes per year, much of this being in salt water. In areas which are particularly attractive to fish farmers there may be significant interactions with other water users.

4.18 Contamination of rivers by fish farms can be caused in two ways. First, the intensive rearing of fish leads to locally intensive discharges of effluent having higher BOD, nitrogen (especially in the form of ammonia), phosphorus and suspended solids. Secondly, it has been suggested that the use of various chemicals, including antibiotics for disease protection and control and biocides to prevent fouling of filter systems may result in contamination unacceptable at a downstream drinking water abstraction point.

4.19 Limitations on the extent of the contamination can be exercised in two ways; good husbandry practices on the fish farm, and consent controls on the effluent. However, problems may arise from the increased pollution load, especially of ammonia and BOD in certain inland waters. **If expansion of these activities is to be permitted, then research will probably be necessary on avoidance of pollution, and on effluent purification.** In particular, the potential for changes in fish food composition, including indigestible filler, should be carefully investigated. This might also reduce those waste components which lead, among other things, to the unsightly occurrence of sewage fungus downstream of discharge points.

4.20 A WAA/NFU/MAFF/DOE/WRC Joint Working Party on Avoidance of Pollution from Fish Farms has concluded from theoretical calculations that the use of antibiotics and other chemicals for disease control and prevention is unlikely to pose a serious threat to other water users. However, the Department of Health and Social Security (DHSS) feel that there is insufficient information to permit a formal assessment. Work by WRC has shown that extremely low concentrations of one chemotherapeutic agent were detectable at an abstraction point downstream from a fish farm which was using an exceptionally heavy dose to control an outbreak of fish disease. The concentrations were considerably lower than the theoretical calculation referred to above had suggested, and none was detected in the drinking water supply. **Research of this nature, which permits a sounder assessment and more confident advice in response to hypotheses of hazard, is to be encouraged.**

4.21 There have been reports of deterioration in wild stocks downstream of fish farms, though it is not clear yet whether there is a relationship between them. **Surveys such as those being carried out by Wessex WA to investigate these situations should be encouraged, and supported by research into fresh water population dynamics in conjunction with MAFF and NERC .**

4.22 As indicated, much of the potential increase in fish farming is likely to be in salt water rather than freshwater and in particular in cages. A particular advantage of salt water cage farming is that in the sea both organic and nutrient inputs are more easily dispersed, though undue build-up of organic wastes beneath the cages can be a problem. DAFS and Stirling University are studying the extent to which such build up may cause ecological problems. An agreed code of practice sponsored by the Highlands and Islands Development Board, NCC, DAFS and SNFU is the aim of this work.

Effects of Gravel Extraction from Coastal Waters on Sea Defences.

4.23 Offshore sand and gravel dredging is expected to increase, especially off the south and east coasts of England, as onshore sources are depleted. Licences are only issued for areas where dredging will not influence coastal erosion or seriously affect fisheries resources. As a result of the former, dredging has generally been restricted to water depths greater than 18m, although detailed site studies may allow this criterion to be relaxed in some cases in the years ahead. We understand that a review of the dredging industry, its development potential and prospects and its interaction with other interests (such as the coastal environment), has been commissioned by DOE. This review is likely to emphasise the need for further research to improve the accuracy of models of waves and sediment movement and to investigate the effects of dredging on coast erosion, fisheries and pollution of the marine environment.

Energy Production

4.24 The energy production industry is the second largest single user of fresh water, abstracting 3 billion cubic metres a year for cooling power stations. The return of this water is carefully controlled and does not have any significant adverse effect; no further research on this subject is required although discharge sites should be watched carefully since the higher temperatures of water from power stations have some ecological effects by providing conditions which are suitable for species not naturally present in the locality. It is possible that such species may adapt to cooler water and spread from these foci.

4.25 **On-shore oil exploration and production** . Exploration licences have been issued covering large areas of the chalk outcrops of southern England and an important area of sensitive coast and shallow-water marine environment in Poole Harbour and licences have been designated in the Jurassic areas of the Midlands. A production well already exists at Humbly Grove near Basingstoke. Activity is therefore in areas of important

water resource aquifers and concern has been expressed about contamination arising from leakage from exploration or production boreholes, from the re-injection of brines and from the use and disposal of drilling muds and cuttings. It is evident that the potential hazards are well recognised and are avoidable given the sensible application of known methods. Water industry interests are protected by consultation procedures and by the statutory provisions of the Control of Pollution Act and Environmental Impact Assessment procedures are being applied at Poole Harbour. While at the moment we see no need for further research into potential impacts it is clearly in the interests of the oil and water industries to discuss and agree codes of operating practice and research priorities and we understand that Southern Water Authority has made some progress towards this end. **We recommend that the Water Authorities Association should initiate discussions with the UK petroleum industry.**

4.26 **Substitute natural gas production.** We understand that the widespread introduction of SNG plant is unlikely before the second decade of the next century. The British Gas Corporation has in hand the development of prototype SNG plant and attention is being paid to disposal of the highly polluting effluents arising from the process. **A continuing dialogue between the gas and water industries is required on the effluent consent conditions to be applied, which may affect the locations chosen for the new plant.**

4.27 **Coal burning.** The contribution from conventional power stations to environmental acidification is the subject of considerable research reflecting the level of international concern. We have discussed acidification issues elsewhere in this report. There are suggestions that the pursuit of cost-effective means of reducing emissions may lead to the introduction of fluidised bed combustion, and there are calls for flue gas desulphurisation to be installed in new power stations or retrofitted to some existing plant. The disposal of the wastes arising from these processes has potential implications for water pollution. There is always a risk that the urgent need to reduce pollution in one sector of the environment will lead to contamination in another and this is why the best practicable environmental option for disposing of a waste should always be evaluated. In the longer term the potential impacts of underground coal gasification will need to be studied but until the methods have been developed the environmental consequences are unclear. **We can only advise that all these matters be kept under continuing review:** this, and any research that appears necessary is primarily the responsibility of the Government Departments concerned.

4.28 **Geothermal energy** . Energy production from highly saline aquifers will present environmental difficulties if the hot water extracted is not re-injected, and the economic penalty of re-injection is considerable. The current proposal in such a case would be to pipe the effluent to sea and would thus limit such a development to coastal areas. The current prognosis for geothermal heating is very pessimistic and the scale of any development in the UK is not likely to be significant. We see no research implications for the water industry here.

4.29 **Nuclear power generation** Nuclear power stations require the circulation of cooling water and those on the coast are associated with areas of warmer habitat as mentioned in paragraph 4.24. The amounts of radioactive substances released from power stations during normal operations are trivial. Larger amounts are released from other nuclear industry plant, especially the British Nuclear Fuel Ltd works at Sellafield. The permissible discharges from all nuclear installations are regulated by DOE/SDD and MAFF, who undertake substantial research and monitoring, and we do not consider any further research is required by the water industry.

4.30 The disposal of radioactive waste materials is an issue of considerable public concern at present. We understand that proposals for the construction of a disposal facility, probably as a concrete-lined trench in clay at shallow (i.e. less than 100m) depth are currently being developed and may be accompanied or followed by proposals for a deeper depository for longer lived intermediate level waste. We are assured that all possible sites will be thoroughly investigated and that the prevention of contamination of aquifers will be a central design requirement. **We endorse this latter judgement, and believe that the responsible water authorities need to be closely associated in the investigation and evaluation process.**

Manufacturing Industry

4.31 Over recent decades there has been a decline in traditional manufacturing industries, and growth of industries based on new technology. This decline, most obvious in the North of England, has resulted in measurable decreases in industrial water demand and there is some evidence of reductions in the quantities of liquid waste discharges. These downward trends in water consumption and effluent discharges have been accelerated by industrial changes, the increasing costs of water supplies and the economies to be made, for instance, by recycling process waters. However, it is not known how much of the reduction is permanent and what increases in demand will occur if economic growth continues at presently predicted rates. The prediction of future industrial water demand is important, and the environmental consequences and costs of any new trend need careful evaluation before major investment decisions are made.

4.32 It is commonly assumed that the "new" technologies are inherently less polluting than the old. This is not necessarily the case. While they generally produce less water-borne effluent, they also handle some particularly intractable materials, including toxic metals. A study of the environmental impact of advanced technology industries in the Bracknell area (6) concluded that the water pollution problems could be contained by the vigorous application of consent conditions on trade effluent discharges and proper attention to handling and storage of chemicals. However the study did acknowledge that there was a lack of information about the environmental effects of certain forms of organic compounds produced and discharged in effluents from pharmaceutical and bio-technology industries. We consider that it is essential that potential environmental impacts are evaluated in advance, and that new industrial processes are planned from the start to minimise such problems. The emphasis should be on prevention rather than cure, and we are not satisfied that research on the industrial side is as thorough as we would wish. There is also a lack of toxicity data on chemicals brought in with raw materials from countries where strict controls, like the Chemicals Notification Scheme, do not apply.

4.33 We have considered elsewhere some of the applications of biotechnology and genetic engineering in agriculture and in waste treatment and we have noted the possibilities of both new problems and new solutions. Manipulation of genetic material and the use of antibiotics carries the risk of dispersing resistant organisms in the environment. Reassuring statements have been made that the escape of engineered organisms to the environment would present no hazard. **However, in our view the risks and potential implications (which go beyond the concerns of the water industry) are such that it is essential to keep new developments under close review.**

4.34 We believe that a great many of the current and foreseeable problems of the water industry arise, or are likely to arise, from the activities of manufacturing industry and we consider that this area requires greater emphasis. **While the primary need is for manufacturing industry to do sufficient research to define the environmental effects of its effluents and products we consider it essential that the potential environmental impact of new industries and products is thoroughly appraised and we recommend that this remains a matter of major concern for Government and the water industry.** Stimulation and development of improved pollution control technology is also required and we return to this aspect in Chapter 5.

Waste Disposal on Land

4.35 The pollution potential of leachate derived from the disposal of household and industrial waste by landfill has been the subject of research for a number of years.

There is now a reasonable understanding of the movement of deposited heavy metals in rocks and soils and the mechanisms that render contaminants relatively immobile within the body of waste. Work is continuing on the fate of organic pollutants coming from landfill sites and ways of controlling or influencing their rate of breakdown. Particular attention is being paid to converting the organic component of landfill to methane gas. Research into predicting leachate movement through fractured rock continues but the problems are considerable. **Information is also required on leachate from wastes treated before deposition .**

4.36 For the future, the DOE Landfill Practices Review Group predicts a move towards larger disposal sites in which control of water pollution hazards will be based on containment rather than attenuation and dispersion principles. This will increase reliance on on-site treatment of leachate to standards which will permit discharge to sewers or direct to surface waters. The Review Group notes that at present there are no full-scale, operational treatment plants in the UK which are capable of achieving the required standards and **we support their view that there is a need for intensive research and development in this area.** We also support the Review Group's suggestion that more attention will have to be paid to the long term integrity of lining and capping materials as a consequence of the move towards large engineered containment landfills. **The development of liners with controlled permeability would afford greater flexibility in landfill design at sites where total containment is not required.** We consider this research crucial to the development of higher standards of containment of potentially hazardous wastes. The recent report by DOE's Hazardous Waste Inspectorate has drawn attention to the need for improved practice in this area (7).

4.37 Much sewage sludge produced in the UK is disposed of on agricultural land. The return of organic nutrients to land is clearly good ecology provided safeguards are observed and this has been stressed by the Royal Commission on Environmental Pollution (8) and the House of Lords' Select Committee on the European Communities (9). Guidelines on the safe disposal of sewage sludge in agriculture, which have been in existence for a number of years, guard against the passage of metals and other contaminants from sludge via plants to human food, against the spread of pathogenic organisms and against damage to the environment. We understand that these guidelines will shortly be revised to take account of recently completed research. We recognise, however, that this research was empirically based and did not seek an understanding of the mechanisms of phytotoxicity and metal uptake of plants. A recent report from the Rothamsted Experimental Station has suggested that contamination by metals could inhibit soil microbiological activity, particularly by blue green algae (10). While we are pleased that this matter is being urgently pursued, the report strengthens our

view that these are areas of important research which should be undertaken in the light of advances in knowledge of plant physiology and against the background of increasing demand to reduce the quantities of metal in human food chains. We also support development work on methods for treating sludge which inactivate pathogenic organisms. **We recommend further research into sludge disposal and agriculture** in view of its economic and social importance especially when outlets for sludge to sea are also being challenged.

Kitchen Waste Disposal Units

4.38 In recent years there has been a considerable growth in the use of garbage grinders for disposal of food and kitchen waste particularly in blocks of flats, luxury houses and restaurants. Their use results in wastes which would normally be placed in dustbins being discharged into sewers for treatment and disposal at sewage works. We have been told that in Bournemouth, disposal units are fitted in 60% to 80% of large blocks of flats. The impact of the use of disposal units on water authorities operations includes:

(a) higher treatment costs due to increases in BOD and suspended solids of between 30% and 60%,

(b) increased difficulties at treatment works arising from increases in grease and oil (35%-50%),

(c) changes to basic design parameters to reflect higher levels of suspended solids and BOD loading per capita,

(d) more rapid take up of available capacity at treatment works requiring an acceleration in capital works,

(e) some increase in water consumption

4.39 While it is unlikely that waste disposal units will be fitted to all houses due to constraints of capital and space, their number does appear to be increasing. **It would therefore be timely for the water industry to investigate in more detail, future impacts on operating costs and design criteria and to consider whether special charges are warranted to recover extra costs.**

CHAPTER 5 INTERNAL TECHNOLOGICAL CHANGE

5.1 Much of the technical innovation in the water industry is driven by the social, economic and external influences which we have identified in this report. The raising of environmental standards stimulates the development of more effective pollution control technology; continued attention to the cost of water services fuels the search for greater efficiency; growth in demand for water results in better use of existing supplies or the development of additional resources and so on. We consider below how these, sometimes conflicting demands, influence technological developments in the industry's main functional areas.

5.2 Currently, the overriding emphasis is on cost cutting which in the water industry means making the best possible use of the capital assets, raising the productivity of the work force and ensuring that the standards to be achieved are appropriate. There is already conflict between this quest for economy and rising demands for environmental quality. The pace of rising expectations is difficult to predict, but long term research should, nevertheless, seek to illuminate and ameliorate these potential conflicts.

Water Resources

5.3 **Demand forecasting.** There is now a fair understanding of the factors that determine potable water demand and we see little need for research into refining predictive models. The major uncertainties in the inputs to models concern industrial water consumption and irrigation demands and we have already recommended further study of trends in these areas. There is considerable interest in the extension of domestic metering and the prospects of controlling demand through tariff structures. In the report on the DOE/Water Industry Joint Study of Water Metering, published by DOE in December 1985, there are recommendations for an extensive programme of research into the costs and benefits of metering. The analysis shows that a large element of the total costs of water supply relates to capital investment to provide sufficient capacity in the distribution system to meet short term summer peak demand from garden watering. Reducing this demand will cut costs. The report also concludes that in some circumstances metering can be shown to be cost effective but there are great uncertainties particularly on the effects of metering on household consumption. There is a need to understand the effect of various tariffs including the peak demand charges which become possible through the introduction of new metering technology. We believe that decisions on the installation of household meters should be based on sound information on costs and benefits **and we endorse the recommendations in the Joint Study Report on the research programme required.**

5.4 **Water economy devices.** Water economy devices provide an alternative or an adjunct to metering as a means of demand management. Research over many years at Building Research Establishment (BRE) has shown that the current 9 litre flush for WCs can be reduced and waterless urinals may be a practical proposition. Other potential engineering solutions to rising water demand include pressure reducing valves, flow limiting devices and trip devices which interrupt flow when a fixed volume has been passed or when persistent, constant flow conditions indicate possible leakage. We believe that research in this field is worthwhile both in the light of the contribution it might make to the more efficient use of water in the UK and because of the potential market for such devices in countries where real problems of water shortage exist. It has been suggested to us that, should water charges become more directly related to consumption, market forces would ensure the steady development of water economy devices. However, there is doubt whether a small reduction in charges would provide sufficient incentive to householders to fit economy devices and additional motivation may continue to be required through the use of water byelaws. **We therefore recommend that the work in this area should continue and urge that the industries concerned seek positively for innovation.**

5.5 **Interbasin transfer.** Research into the quantitative effects of interbasin transfers has provided an adequate basis for the economical use of conjunctive resources. However, concern has been expressed about the ecological consequences of such transfers. By causing significant changes to the volume of flow, and to its distribution in time, these may affect the spawning grounds of salmonids. Furthermore, changes in the physical characteristics and chemical composition of flow may affect the distribution of plant and animal populations, the growth of individuals and the return to spawning grounds of migratory fish. There is also concern that an inadequate basis exists for predicting the ecological effects of compensation water releases and reductions during droughts, particularly the effects on fish populations. **As noted in 3.18, we recommend further research to clarify how changes in river flow regime affect plants and animals, and fish reproduction, survival and growth.**

5.6 **Reservoirs.** It is unlikely that there will be the need for more than a few new reservoirs in the UK during the next twenty to thirty years, especially if the introduction of pricing measures eliminates the current rate of increase in demand. The immediate and longer term concerns are for the condition and safety of existing dams and the requirements for inspection and maintenance. Current work at BRE indicates that the majority of in-service incidents and failures affecting embankment dams have been caused by internal erosion of the clay cores and research to improve the understanding of the performance and deterioration of old dams is being pursued

vigorously. Associated with this work is the development of methods and instrumentation for investigating the condition of old embankment dams to assist with the statutory inspection requirements contained in the Reservoirs Act 1975, now largely implemented. New geophysical techniques will undoubtedly continue to emerge in the future, and it would be worth performing individual trials with the most promising of these new developments as they become available, (eg, the current BRE trials using infra-red thermography to investigate leakages). Other non-geophysical aspects of research into dams are also important and include the application of risk analysis techniques to the probability and consequences of failure, dam break analysis, improved methods of flood estimation and the design of embankments to withstand overtopping. The Committee takes the view that the requirements for research on dams have been carefully evaluated and that considerable progress is being made. However, possible deterioration of concrete dams appears not to have been studied as fully as that of embankment dams. **We recommend that such an assessment should be made and that a centre of expertise such as currently provided by BRE should remain available to support Government, the industry, and private reservoir owners in the future.** Present capacity may be adequate but should not be permitted to decline further.

Water Supply

5.7 **Water treatment.** Research and development into water treatment methodology is concerned with cutting costs and dealing with the health-related water quality matters which remain unresolved. In our opinion the development of enhanced treatment techniques is in advance of current needs if these are to continue to be defined primarily in terms of demonstrable risks to health. However radical ways of treating water more economically to the accepted standards need to be sought. We note the work on Instrumentation, Control and Automation (ICA) which is aimed at better control philosophy, on expert systems as an aid to the design of small plants and on more reliable equipment for ensuring disinfection at small rural plants. The water supply industry has traditionally relied on large concrete structures and modern process engineering philosophy found in other industries has not generally found favour. We support the work on the Siro Floc process, a transfer of technology from the mining industry. In view of the extensive plant replacement programme still to be carried out **we recommend that an urgent review of potential new water treatment technology is carried out with particular reference to the application of technology currently in use in other industries.**

5.8 Further research on ways of improving water supply quality can only be justified if knowledge of the health implications of, for example, trace organics, points to the need for more sophisticated treatment methods or if it is considered that the margin of insurance against low or unproven risk should be widened. If more stringent drinking water standards are introduced as a reflection of the trend towards a "precautionary approach" then new treatment methods may be required. Of particular concern is the removal of nitrate from potable supplies and although methods have been devised **we consider that further development of reliable and cheap plant is required.** We have also considered the possibilities of treating potable water at the point of use - to avoid the problems of deterioration of water quality in the distribution system - but we have concluded that enhancement of central treatment facilities and attention to the distribution system would be a more economical proposition. We conclude that research on treatment remains a long-term requirement, closely linked to the toxicological studies we have already advocated.

5.9 Some preliminary work has been undertaken to investigate means by which the formation of compounds by the chlorination of organic compounds already present in source waters can be minimised or alternatively means by which they can be removed during treatment. This work has tended to show that effective treatment will involve more stringent and costly treatment than for taste and odour control. **A great deal more research is needed however to evaluate alternative forms of disinfection** which minimise the formation of potentially hazardous by-products while maintaining disinfection efficiency. **The removal from water of mutagenic compounds and their precursors by processes involving activated carbon and other possible adsorbents needs to be thoroughly investigated.**

5.10 **Water distribution.** The operation and maintenance of water distribution systems is one of the major costs of water undertakers. The first major stage of an R&D programme to develop a more economical approach was completed at the beginning of 1986 with the publication by WRC of a manual on the Operation, Maintenance and Renovation of Water Distribution Systems. It has been estimated that, by the year 2000, some 15% of supply networks may be conveying waters different in composition from those conveyed today. This will be due in part, to the trend towards blending water from different sources. Guidelines designed to limit the water quality problems arising from the mixing of different source waters in distribution systems have been published. Also, a rational approach to leakage control has also been developed and is being implemented by the water undertakers. The Committee believes that past and current research together with the planned future programme reflects the importance the industry attaches to the problems of water distribution and we have not identified serious gaps in the coverage. **In the longer term we support the**

industry's intentions to explore the possibilities of improved pipeline materials and the application of instrumentation, control and automation, including expert systems, to distribution.

5.11 There are, however, two areas in which progress is inadequate and this may reflect organisational difficulties and lack of clear responsibilities. **First, there is a need for a greater understanding of the effects of traffic loading on buried services.** In particular, the effects of pavement restoration and the dynamics of vehicle suspension systems, need clarification so that appropriate measures can be taken to preserve the integrity of water mains as part of the whole road/soil/pipe structure, whose behaviour is inadequately understood. The need has been recognised for some time by the National Joint Utilities Group and we recommend that the research should now proceed. Secondly, we recognise the considerable interest worldwide in trenchless pipe laying techniques. An international conference in 1985 has now led to the establishment of the International Society for Trenchless Technology through the close involvement of the Institution of Public Health Engineers. Considerable effort is being devoted to the development of new techniques which have been notably successful in Japan and Western Germany in particular. In the UK, attention has concentrated on studies to identify the opportunities for new techniques and to define the precise requirements to meet UK circumstances but the crucial step of initiating development work has yet to be taken. This may be because the cost of development is likely to be beyond organisations individually. We believe there is scope for a joint venture involving the water industry and construction firms. Because the saving of the social costs associated with open excavation is potentially so high **we consider that Government should monitor progress and should consider whether financial contribution to the development costs would be appropriate.**

5.12 **Intake protection.** The vulnerability of water supplies drawn directly from rivers flowing through developed catchments has been recognised for some time and water undertakers have been advised to provide at least 7 days' bankside storage. In many instances, however, this recommendation has not been adopted. An incident in North Wales in 1984 led to contaminated water being supplied to about 2 million consumers. Lessons from this incident have been disseminated to all water undertakers and the long term programme of research underway at WRC is highly relevant. **The WRC programme is tied in with research at universities and within the industry to develop more effective monitoring systems using both biological and physical/chemical sensing systems. Risk analysis should also be applied in the development of operational procedures for handling pollution incidents and in the design of works** and we recommend that this work continues. **We also recommend that developments in monitoring**

technology in other industries should be explored with a view to application in the water industry.

Sewage Treatment and Disposal

5.13 In chapter 2 we noted the trends towards higher standards of environmental protection and in chapter 3 we examined gaps in our knowledge of the interactions between waste disposal activities and the natural environment. We now turn to the technology of waste disposal and consider the needs for research into the technical solutions.

5.14 **Trade effluent treatment.** It has been suggested that development of industrial waste water treatment processes is being neglected because existing consent conditions provide little incentive for improvement and what little work there is suffers from fragmentation. We recognise the need to stimulate development of British equipment in areas with commercial potential and **we recommend discussion of common research requirements of the water and manufacturing industries.** Whether or not trade effluent treatment should be stimulated by Government action and subject to some central co-ordination is a matter for consideration by DOE and the Department of Trade and Industry. **We recommend further study of the implications** and some element of pump priming using Government funds should not be discounted.

5.15 **Sewage treatment.** We see the major influences on sewage treatment research to be the quest for cost cutting and for increasing reliability and improving the removal of specific substances to meet rising environmental standards. There is considerable short and medium term research into these aspects at WRC and elsewhere which will bring refinement of the conventional technology. In this context we note the considerable interest now being taken by WRC, the water authorities and consulting engineers in root-zone biotechnology for treatment of sewage from small populations. In the longer term,progress will depend on speculative work where the final application and uses, if any, are less easy to define and quantify. This work is unlikely to be undertaken by private industry but will instead be the function of pure and applied engineering and science departments in universities and research organisations. If the opportunities offered by more speculative or more abstruse academic work are not to be missed it is essential that the water industry develops closer links with academic research. **The Committee recommends that the possibilities for collaborative research by the industry and universities should be explored in areas of biotechnology such as recombinant DNA methods for enhanced reaction rates, bio-fuel cells, biological sensors for ICA, enzyme technology and liquid membranes.** Relatively little is known about the way treatment systems behave at the

molecular level and greater understanding should help in optimising system design and operation. **We believe that work on the molecular biology of waste water and sludge treatment processes should be developed and supported.**

5.16 **Sludge treatment and disposal.** Sewage sludge treatment, handling and disposal is still the single largest problem facing the industry and will be for the foreseeable future and it must therefore be an important part of both short term and long term research and development. In the future, the problems are likely to be exacerbated by further restrictions on the disposal options both on land and at sea. Research is required to confirm or refute current assumptions regarding the environmental safety of existing disposal options so that the best practicable environmental option is chosen and we have discussed this aspect in Chapter 4. Research is also required to improve the quality of sludge so as to maintain the greatest number of disposal options and in this respect the reduction of concentrations of toxic metals and persistent organics requires further attention. Levels of such materials can be reduced by tightening controls on industrial discharges to sewers or by additional treatment at the sewage works. There is much existing work on developing the optimum metal reduction strategy and we recommend that it should be expanded to include a thorough examination of the alternatives and if necessary the development of metal removal treatment methods.

5.17 **Waste recovery.** The potential use of sewage sludge as raw material for the manufacture of animal feedstuff has been recognised for many years but the economics and the difficulties of dealing with the contaminants have precluded commercial development. It is possible that future constriction of disposal options, reductions in toxic metal contents or developments in biotechnology may make re-use of sewage sludge a practical and economic proposition. **We consider that the industry should support a modest programme of work in this speculative area including composting and conversion to animal feedstuff and oil.**

Drainage

5.18 **Sewerage.** 96% of all households within the UK are connected to the public sewer system. There is no obvious immediate alternative to water-borne sewage so, for the foreseeable future, capital expenditure will be increasingly directed towards rehabilitation of the existing sewer stock rather than on building new systems. The philosophy for planning and executing such work is set out in the WAA/WRC Sewerage Rehabilitation Manual. The full benefits of the approach described in the manual will only be realised by advances in trenchless pipelaying and sewer renovation and through the development of long lasting materials for sewer lining or

new pipelines. We have discussed above the common need to develop less disruptive pipelaying techniques for water distribution. It is apparent to us that considerable progress has been made in the development of sewerage and sewer renovation 'hardware' and the long term needs will be met as a consequence of the continuing high level of activity and interest. We do not see this as an area where new research is as crucial as the application of knowledge already available, but the latter is obviously of very great social importance in view of our ageing stock of sewer systems.

5.19 **Urban drainage.** Traditionally the approach to urban drainage has been to get surface runoff and domestic sewage into and through the sewer system as quickly as possible to the point of final discharge or treatment. Where flows concentrate, problems of flooding and pollution may occur. In the interests of economy and pollution prevention it is now becoming necessary to re-examine these traditional concepts and design practices. Flow attenuation within the sewer system is being used increasingly to reduce hydraulic overload and small scale schemes have been built in North America and Europe to provide above ground detention and attenuation. "Real time" control of sewerage linked with radar rainfall forecasting is becoming a practical proposition. The basis for these developments in improving hydraulic performance has been provided by research and **the major future requirement is the construction of full scale demonstration sites to refine the techniques and establish the unit costs.**

5.20 The pollution impact of sewerage and the relative contribution of surface water runoff, sewage works effluent and storm sewer overflows is more problematic. As yet we are unable to predict the quality of storm water overflows or surface water discharges with a desirable degree of precision. Neither can we predict the effects of such intermittent pollution loadings on the receiving water course. It is consequently impossible to make scientifically justifiable decisions about the best options for further improvement of river water quality. It may for instance be cheaper to tackle the intermittent discharges or the diffuse sources of pollution than to upgrade sewerage and sewage treatment works. **A programme of work on quality modelling involving WRC, several water authorities, Hydraulics Research and some universities has been started and the Committee recommends that the programme should be carried forward urgently.**

5.21 **Land Drainage** Failures of land drainage cause considerable damage to life, property and agricultural land, and are not infrequent even in Britain. A poorly understood feature of flooding is flow which occupies both the channel and associated flood plain. The height to which a flood rises and its speeds of growth and recession all depend on this compound channel flow. It also has long term consequences for the

geometry of the channel itself, associated with its erosive effects. Research initiatives concerning this problem at several British universities are being coordinated by an SERC Working Party on Flood Channels, which has secured the use of a large new experimental facility at Hydraulics Research, Wallingford. In connection with the development of a programme for that facility a coordinated research strategy is being documented by the Working Party. Over the past six years current expenditure on land drainage in the UK has averaged £73M per year. **The projected research programme has the objective of obtaining better value for this expenditure and increasing the competitiveness of British consultants seeking overseas work in this field and we commend it.**

Remote Sensing

5.22 At present, the operational use of remote sensing techniques by the UK water industry is limited to weather radar although some experimental work on water pollution observation is being undertaken using satellite images and aerial photography, including photography from model aircraft. Worldwide development of satellite remote sensing technology is developing applications in water resource management, measurements of some water pollution parameters and other aspects of environmental monitoring. However, the existing technology is of greatest use where relatively coarse and unsophisticated measurements are required over large areas. Considerable development is required to provide sufficiently accurate data on a wide range of physical, chemical and biological water parameters by methods which are practical and cost effective.

5.23 We know that work on remote sensing at the British National Space Centre is addressing data collection issues which would embrace water industry applications and closer links are being established with the work of the EC Joint Research Centre at Ispra. A new member of DOE's Chief Scientist's Group has been appointed to promote space and remote sensing developments relevant to policy interests. The NERC also has close links with the British National Space Centre and has established a Joint Research Council Remote Sensing Committee. **We strongly recommend that the water industry keeps abreast of developments so that it is in a position to respond effectively to the emerging technology.**

CHAPTER 6 MONITORING AND THE COLLATION OF DATA

Monitoring

6.1 Monitoring and surveillance are undertaken for a wide range of purposes. Much of the activity is of a routine nature to check compliance with legislation or to measure and record trends. Whether consent conditions are based on effluent standards or environmental quality objectives, monitoring is necessary to confirm that the aquatic environment is in a satisfactory state and that controls are being complied with.

6.2 **Responsibilities for monitoring** Water authorities and river purification boards have undertaken extensive freshwater monitoring programmes generally measuring a series of some 20 determinands at the tidal limits and confluences of major rivers and in the vicinity of major discharges. This programme has already placed a considerable strain on resources, and further burdens are arising from the requirement under the legislation, to measure chemical substances in discharges and receiving waters. The need for economies within the activities of the water authorities has, in recent years, led to some reduction in river flow gauging; **the Committee feels, however, that these reductions have now become excessive, bearing in mind that natural river flow represents an integrated measure from which fluctuations in climate can be detected.**

6.3 The UK has an obligation to undertake monitoring under several international agreements (EC; Oslo Convention; Paris Convention). To date, the results of monitoring have confirmed the effectiveness of the UK approach to pollution control (see chapter 2). There is an active national Marine Pollution Monitoring Management Group (MPMMG) which aims to ensure that monitoring of the marine environment by the several organisations involved meets all national and international needs, serves a common purpose, is carried out in a similar way, and produces comparable data. The MPMMG carries out regular reviews of monitoring activities, monitoring methodology and research needs. We are satisfied that the activities of this Group are adequate for their purpose. The results of routine monitoring activities are usually evaluated by the programme organiser and not by MPMMG. However, in many cases, data are passed back to government departments in order to meet international obligations and MPMMG acts as a co-ordinating body in this context. A summary of results is published in the DOE Digest of Environmental Protection and Water Statistics (11). These arrangements seem adequate.

6.4 We do, however, foresee some difficulties ahead. As the Control of Pollution Act is enforced, water and river purification authorities will find it necessary to expand their monitoring of estuarine and coastal waters. Such expansion is important in defining long term trends, identifying future problems and aiding international discussion. We have been informed that although they can satisfy their statutory obligations at present, financial constraints may make it difficult for them to fund any expansion. **We consider that a way out of this difficulty needs to be found.**

6.5 **Research requirements** Research in the sphere of compliance monitoring has been more concerned with the development of statistical sampling procedures and the development of data handling than the methodology of measurement as such. However, as indicated in chapters 2 and 3, there is a strong need for major improvements to the methodology used, for example, to assess the long term trends in the chemical composition of fresh waters and in the structure and density of freshwater communities. These trends are particularly difficult to distinguish against the background of "noise" associated with the natural fluctuations in the chemical and biological features of water bodies. Many questions remain which, if they are to be answered, require sustained research effort into the development of monitoring methodology. Examples of such questions are the following: What organisms give the best indication of change in fresh waters? What are the advantages and disadvantages of biological, as opposed to physical monitoring? Can pollution effects be adequately separated from other environmental change by biological monitoring? What is required of a sampling procedure to pick up local and national change? **To answer such questions, a long term and multi-disciplinary programme of strategic research is required, the purpose of which must be to understand how organisms respond to their physical and chemical environments and how organisms are inter-related within their communities.**

6.6 In many cases, chemical monitoring involves the measurement of very low concentrations and there is a need for new analytical methods and increased attention to analytical quality control (AQC). Research on method development as currently carried out within MPMMG in the marine areas, use of automated techniques and improved data handling has given increased impetus to these developments. Three particular areas of development stand out as of high priority:

a. there is increasing concern about the ability to interpret the significance of chemical determinands both in terms of their long term environmental impact and the effects of transient events. Attention is therefore being given to the use of biological indicators in an attempt to integrate the combination of short and long term changes;

b. water abstractors are concerned about their ability to detect pollution incidents which can pose threats to water supplies. Research is in progress to develop broad-band sensors using fish or other organisms to give warning so that intakes can be closed or other remedial action taken. There is also a need, and a potential, for the development of non-invasive sensors for water quality measurement and control;

c. the increasing tendency to rely on numerical standards in international legislation leads to a need for adequate data on the effect of substances, often of a complex nature, on aquatic organisms. Adequate laboratory test systems for assessing likely chronic effects coupled with field assessment methods need further development so that standards are set at levels which are safe but not punitive to water industry operations.

6.7 The importance of many pollutants is determined by the total amount delivered, or load. To compute loads with accuracy, it is essential that river flows also be measured accurately, and flow measurements need to be recorded at least as frequently as the water quality determinands. The methods now used to estimate flows at sites where flow-gauging has been discontinued may well be inappropriate if and when changes in climate are appreciable.

6.8 CERRG and MPMMG have reviewed the need for research on marine monitoring methodology. They consider that there should be more work to quantify contaminant inputs from various sources (including methodology of measurement and studies of the fate of pollutants). More work on biological monitoring methods, especially to improve the interpretation of results of the wide variety of tests now undertaken at organ, individual or population level, is also needed. We concur with this assessment.

Data Bases

6.9 The Committee's terms of reference are specifically to examine the needs for research. However, most applied research has as its starting point the study of existing literature and archives. This prevents duplication and defines the gaps in existing knowledge so that limited funds can be put to maximum effect. Archives of data, such as the National Well-record Collection maintained by the NERC British Geological Survey and the surface water records maintained by the Institute of Hydrology, therefore have an important role to play in research. The value of such archives must be assessed not only in terms of the frequency of usage, but also in terms of the nature of the events which would require them to be consulted. For

example the Aberfan disaster initiated extensive searches of the groundwater archives; the damaging floods of 1953 caused significant pollution of coastal areas and wells and the Well-record Collection was widely consulted; the 1968 flood led to the establishment of flood flow archives at the Institute of Hydrology and to their use by the UK Floods Study. Currently, the rise of groundwater levels below London and other conurbations is threatening engineering structures and building foundations; models to forecast the impact of this depend heavily on archived data extending back to the mid-nineteenth century.

6.10 Maintenance of archived data is an important but presently unfashionable activity which always comes under particular threat at times when funds available for research are shrinking. **The Committee recognises the great importance of archived data as an essential basis for applied research, and recommends that the National Well-record Collection and the surface water and groundwater archives be given proper recognition as a national resource which should be adequately maintained by their potential users,** DOE, MAFF, the Department of Energy, SDD and others: one possibility would be the contribution of a levy from potential users in proportion to their expenditure on water-related research.

6.11 We have considered how far the results of current monitoring should be consolidated in a further archive bearing in mind that the Joint Monitoring Group of the Oslo and Paris Commissions already has plans to produce a consolidated archive of marine monitoring data submitted by national authorities (MAFF, DAFS, WAs, RPBs). We do not consider the benefits of a single national data base, collecting all the results, would justify the costs. But we believe that water authorities should note the data they collect systematically, and that exchanges between their data centres and a capacity to collate their consents should be secured by the use of a single determinand dictionary. We note that this is the present intention and endorse its importance. We regard this whole area of archive maintenance as of high priority, although we consider that the need is largely for protection of existing levels of effort rather than growth.

CHAPTER 7 SUMMARY OF RESEARCH RECOMMENDATIONS

7.1 Our recommendations for research are tabulated below. We emphasise that the division between "major needs" and "related important topics" reflects not only relative urgency but also the significance of the results of the research to the future of the water industry and the development of water policy. We consider that all these topics require evaluation.

7.2 We also tabulate a list of supplementary recommendations which relate to future liaison on research needs, the need to keep abreast of developments in certain emerging technologies and the importance of protecting or expanding data collection activities. We regard all these as important features in the consideration of longer term research needs.

7.3 Certain additional recommendations on future organisation are made in Chapter 8, paragraphs 8.5 and 8.16-8.19.

ENVIRONMENTAL RESEARCH

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Environmental Protection	• Study the merits and investment implications of combining an EQO/EQS approach with emission limits for black list materials (2.7) • Study dispersion and neutralisation mechanisms and develop predictive models for hazardous substances (2.8) • Expand basic research on the physiological and biochemical responses of aquatic organisms to pollution in the context of long term investigations of their population performance (2.10)	• Research on the properties and environmental pathways of wastes and the costs of alternative disposal methods in order to assess the BPEO (2.12)
Drinking Water Quality and Health	• Identify non-volatile organics in potable water (2.14) • Investigate effects of distribution systems on chemical quality (2.14) • Continue work on basic toxicological and medical research (2.17, 2.19) • Examine effects of water treatment on pathogenic viruses and protozoa (2.20).	• Chemical interactions in water and the effects of treatment. (2.14) • Speciation of trace metals and metalloids (2.15) • Methods for assessing non-oral intake of chemicals in water (2.16) • Improvements in virological analyses of water (2.20) • Validation of bacterial indicators of microbiological quality (2.20).

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Social and Economic issues	• Develop methodology for the application of risk analysis in the water industry (2.27)	• Develop methods for quantifying public attitudes on environmental matters (2.26) • Produce a generally accepted method for the evaluation of environmental benefit (2.28)
Climatic Change	• Evaluate the need for new research on the implications of climatic change for the hydrological cycle and water management (3.6).	
Fresh Waters	• Continue basic research on hydrological and hydraulic processes for the purposes of predicting run-off and recharge to groundwater (3.7), sediment transport and effects of subsurface flow on water quality (3.8) • Investigate occurrence, causes and effects of contamination of groundwater by trace organic substances (3.12)	• Develop engineering solutions to land drainage and flooding problems which are more in sympathy with the natural environment (3.9) • Further consideration of research into the quantification of intangible benefits and disbenefits of land drainage, flood protection and coastal works (3.10) • Develop economic methods for control of eutrophication in fresh waters (3.13)
Acidification		• Support work of UKAWRG and close consideration of its future research proposals (3.16)
Freshwater Fisheries		• Develop understanding of salmonid and coarse fisheries management and the impact of environmental changes (3.18, 5.5) • Re-examination of EIFAC standards, particularly in relation to marginal coarse fisheries (3.19) • Assess impacts of recreational use of water (3.20)

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Marine Environment	• Develop understanding of the processes determining water quality and simulation models to predict the response of marine ecological systems to pollutant inputs (3.21)	• CERRG recommendations for physical, chemical and biological research in the coastal and estuarial environment (3.24) • Surveillance of eutrophication and its consequences in coastal waters (3.25)
Sludge Disposal to Sea	• Assess the costs and feasibility of establishing an integrated field and laboratory based programme of work to evaluate new approaches for monitoring the effects of sewage and sludge disposal to sea. (3.32)	• Examine the dynamics of uptake and loss of persistent substances in sediments (3.26).
Sea Outfalls and Bathing Waters		• Assess effects of fresh water dilution, turbidity and weak sunlight on the purifying action of salt water (3.33)
Shellfish Contamination		• Continue research into effectiveness of heat treatment and new methods of purification of shellfish subject to viral contamination (3.35) • Study of methods of reducing faecal organisms including viruses in sewage effluents and environmental consequences and costs (3.36)

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Agriculture, Forestry and other Land Uses	• Evaluate water quality and other implications of changing agricultural practices including cropping patterns (4.5), fertilizer usage (4.6), pesticides (4.7), animal slurry (4.9), silage (4.10), and irrigation (4.12).	• Seek better methods of forecasting agricultural trends (4.3) • Assess effects of afforestation on catchment run off quantity (4.14) and quality (4.15), and the costs to the water industry of alternative forest planting and management techniques (4.16)
Fish Farming		• Methods of avoiding pollution from fresh water fish farms (4.19) • Identification of fate and effects of antibiotics used in fish farms (4.20) • Effects of fish farms on wild stocks (4.21)
Industrial and Other Trends		• Investigate impact of kitchen waste disposal units on operating costs and design criteria of sewage works (4.39)

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Waste Disposal on Land	• Further study of the effects of sludge disposal on soil fertility and the long term implications of sludge disposal to land (4.37)	• Investigate effects on leachate of treatment of wastes before deposition (4.35) • Develop full-scale operational landfill leachate treatment plants and liners with controlled • permeability (4.36)
Monitoring and Collation of Data	• A long term and multi-disciplinary programme to develop understanding of how organisms respond to their physical and chemical environments and how organisms are inter-related within their communities (6.5)	

ENGINEERING AND PROCESSE EARCH

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Water Demand	• Assess the implications of domestic metering and the prospects of controlling demand through tariff structures (5.3)	• Continue the development and application of water economy devices and seek innovations (5.4)
Water Resources and Reservoirs		• Assess possible deterioration of concrete dams (5.6).
Water Treatment	• Develop reliable and cheap plant for removal of nitrate from potable water (5.8). • Evaluate alternative methods of disinfection and means of removing mutagenic compounds and their precursors (5.9).	• Review of technology used by other industries and its potential application for water treatment (5.7).
Water Distribution		• Explore the possibilities of improved pipeline materials and the application of instrumentation, control and automation, including expert systems, to distribution (5.10).
Intake Protection	• Develop effective water quality sensors using biological and physical/chemical sensing systems (5.12) and application of risk analysis to operational procedures for handling pollution incidents and the design of works (5.12)	• Developments in monitoring technology elsewhere should be explored with a view to application in the water industry (5.12)

	MAJOR NEEDS	RELATED IMPORTANT TOPICS
Sewage and Trade Effluent and Treatment Sludge Processing	. Study the implications of stimulating of development of British pollution control equipment and instrumentation (5.14) . Explore the possibilities of collaboration between the water industry and universities on the application of advanced biotechnology to sewage and sludge treatment (5.15). . Expand existing research on the reduction of toxic metals and persistent organics in sewage sludge (5.16).	. Discussion of common research requirements on trade effluent treatment of the water industry and manufacturing industry (5.14) . Study of the molecular biology of waste water and sludge treatment processes (5.15). . Support for a modest programme to investigate the possibility for re-use of sewage sludge (5.17).
Sewerage		. Improve hydraulic performance of sewerage systems including flood attenuation and control linked to rainfall forecasts (5.19) . Continue work on predicting and modelling the pollution impact of storm water runoff and overflows on rivers (5.20).
Land Drainage		. Support for programme of work coordinated by the SERC Working Party on Flood Channels (5.21).
Underground Services	. Develop understanding of the effects of traffic loading on water mains and sewers (5.11). . Monitor progress on development of trenchless pipe laying techniques and consider a financial contribution to development costs (5.11)	

SUPPLEMENTARY RECOMMENDATIONS

Social and Economic issues

- Water authorities should discuss with MAFF, the NCC and the Countryside Commission the advantages of new design and management of drainage schemes so as to protect important wetlands, grazing marshes and water meadows (2.21)

- Discussion within the Regional Councils for Sport of research into forecasting future demand for boating and angling and the economic processes and management systems for matching supply and demand (2.23)

Agriculture, Forestry and other Land Uses

- Effective links should be established between the Advisory Committee Structure established under the Food and Environment Act and the research commissioning machinery of the Agriculture and Environment Departments so that greater prominence is given to the environmental aspects of the production and use of pesticides (4.8)

- Monitor the development and impact of the application of biotechnology and genetic engineering in agriculture (4.11)

- An assessment of likely trends of afforestation should be made and the actual situation should be carefully monitored (4.13)

Industrial and Other Trends

- The Water Authorities Association should initiate discussions with the UK petroleum industry about impacts of on-shore oil exploration and production (4.25)

- A continuing dialogue between the gas and water industries is required on the effluent consent conditions for future SNG plant (4.26)

- Keep under review environmental consequences of fluidised bed and combustion, flue gas desulphurisation and underground coal gasification (4.27)

- Water authorities need to be closely associated with the investigation and evaluation of nuclear waste disposal facilities (4.30)

- The risks and potential implications of the manipulation of genetic material and the use of antibiotics are such that it is essential to keep new developments under close review (4.33)

- It is essential that the potential environmental impacts of new technologies are evaluated in advance and that industrial processes are planned from the start to minimise problems. This remains a major concern of Government and the water industry (4.34).

SUPPLEMENTARY RECOMMENDATIONS

Remote Sensing

- The water industry should keep abreast of developments in remote sensing so that it is in a position to respond effectively to emerging technology (5.22)

Monitoring and Collation of Data

- The reduction of river flow gauging by water authorities has now become excessive bearing in mind that natural river flow represents an integrated measure from which fluctuations in climate can be detected (6.2)

- Some means of funding an expansion of monitoring of estuarine and coastal waters needs to be found (6.4)

- The National Well Record and the surface water archive should be given recognition as a national resource which should be adequately maintained by their potential users (6.10)

CHAPTER 8 ORGANISATION OF RESEARCH

8.1 Our final task has been to examine the organisation of water research in the UK and the means for ensuring that research into the longer term issues and opportunities is not neglected. We have considered, in broad terms, total spending on water research in the UK, co-ordination arrangements and the need for a permanent body to keep the issues we have addressed under review.

Spending on Water Research

8.2 The main components of water related research in the UK are shown in Table I.

TABLE 1 WATER RESEARCH IN THE UK - £M pa (1)

	INDUSTRY			GOVERNMENT			RESEARCH COUNCILS			UNIVERSITIES POLYTECHNICS
	WRC	WA	WCos	DOE	MAFF/DAFS	OGD	NERC	SERC	AFRC	
	(2)	(3)		(4)	(5)		(6)	(7)		(8)
Water resources, treatment and distribution	2.9	4.4		1			0.9			0.5
Sewage treatment, disposal and sewerage	5.1	2.6		0.8		1.5	-	0.5		0.6
Flooding, land drainage and coast protection	-	0.4		0.4	2					0.1
Environmental Research - inland waters	3.4	0.9		0.6	1		6.1	0.1		
- coasts, estuaries and seas	0.7	0.1		0.8	4		8.6	0.5		2.5
	20.5			12.1			16.7			3.7

Notes

1 Figures are for 1983/84 or 84/85. 2 Excludes DOE and commercial contracts.

3 Estimated in house expenditure, excludes WRC subscriptions.

4 Water Directorate programme. Other DOE relevant research estimated at £1m pa.

5 Includes demographic research and marine ecology/productivity studies, as well as research associated with disposal or dumping of contaminants in the marine environmen

6 Excludes commissioned research.

7 Includes estimated proportion of large AFRC programme on water, nitrogen, crop productivity, farm wastes.

8 Estimated from known commissions and a project count. Likely to be an underestimate.

The figures are approximate because of the difficulties of quantifying all the research and distinguishing between research and monitoring. We are aware that many other organisations support research of some relevance to our investigations including other research councils and Government departments, plant and chemical manufacturers, nationalised industries and conservation and recreational groups but we believe the figures cover the main relevant activities.

8.3 A judgement on the adequacy of the research effort should strictly take into account research done overseas not just into the international issues like climatic change or the condition of the seas but also into basic environmental processes, human health and technological development. However, while we are aware of the relevance of some overseas research to UK needs, we have not been able to carry out a full analysis.

8.4 Clearly there are many organisations involved in funding and carrying out water-related research, and expenditure is substantial - although the House of Lords Select Committee on Science and Technology showed in their report on the Water Industry that the industry spends proportionately far less on research than the four other utilities, coal, gas, electricity and telecommunications. This, in itself, need not imply that anything is wrong. The volume of research required must reflect need, and the cost will be affected by "sophistication factors" which vary from industry to industry. Justification for research should also reflect the potential cost savings. We note that WRC, in compiling its Research Programme 1985-1990, examines various areas of water industry expenditure. For example, annual spending on sewerage and water mains rehabilitation is put at £210M, capital spending on water treatment is £70M and on water treatment £60M. Annual costs of the industry's sewage sludge disposal operation is estimated to be about £200M and future constraints on existing methods of disposal could increase costs by £70M. With expenditure on this scale we believe that even small proportional savings are likely to be greater than the costs of the research needed to achieve them.

8.5 While it is right and proper that our report should concentrate on the research required for problems that are presently perceived, however indistinctly, on the horizon there will be other problems, particularly within the natural environment, which cannot be perceived from our present viewpoint. The only way of providing against these is to sustain a strong base of strategic research. This has been a feature of the recent past and the work has borne much fruit in terms of better understanding of the physical, chemical and biological properties of fresh and marine waters. For this reason we attach importance to the maintenance of strategic programmes by NERC, the Fisheries Departments and DOE. **We recommend that the level of support for such work be kept under continuing review by our successor body.**

8.6 The value of a multi-disciplinary approach to long term research has been recognised for some time. For instance, NERC adopted this approach in its "Special Topics Programmes", SERC have adopted a multi-disciplinary approach to research in the fields of marine technology and engineering. WRC is able to create multi-disciplinary teams across its three laboratories and enlists support from other specialist disciplines outside its organisation. CERRG and MPMMG have both endorsed the importance of this approach in their particular fields. We commend the multi-disciplinary approach to those commissioning research and caution against over-narrow contracts that exclude relevant studies in linked and supporting disciplines.

8.7 In our review of longer term needs we have not identified so many or such large gaps as to conclude that a major increase in expenditure and efforts is required. Our findings call for a new emphasis on research in certain areas listed in Chapter 7. We have not had time to work up our proposals to the degree of detail needed to cost them precisely nor have we examined existing projects in sufficient depth to assess with much confidence the effect of our proposals on the total water research budget. However, provisional estimates by some members of the Committee suggest that our recommendations are broadly equivalent to 5% of the total in Table I. We consider that the various organisations supporting water research should now examine our recommendations against their existing programmes in sufficient depth to enable project details to be drawn up and costed and appropriate adjustments made where necessary. This is an essential first step in implementing our recommendations and progress should be monitored under the successor arrangements proposed in 8.18.

Co-ordination

8.8 We recognise that many different organisations have a legitimate interest in water research, and should continue to support the work they require in order to discharge their functions. In simple (doubtless over-simple) terms this means:

(a) Government has the responsibility for determining water management policies on behalf of the public. To this end, Government (DOE in particular) must ensure that Ministers are provided with appropriate research and monitoring results. These permit the negotiation of pollution control policies in Europe, the establishment of appropriate quality objectives at home, the judgement of bids for water authority finance, the reconciliation of conflicting policies affecting water resources and the promotion of sensible new policy initiatives. The Scottish and Welsh Offices need to ensure that the particular needs of those countries are adequately catered for, and MAFF/DAFS have a particular

responsibility for research that defines the objectives, standards, and controls, needed in the interests of commercial fisheries and marine ecosystems. All these bodies have an interest in strategic as well as short-term applied research;

(b) The water and river purification authorities must ensure that they have sufficient knowledge to meet their statutory responsibilities, to maintain water quality, set discharge conditions, apply European and domestic legal obligations, maintain a capacity to supply waters of a quality that keeps pace with increasingly stringent standards and treat wastes and dispose of sewage sludges in an environmentally responsible way;

(c) Private sector industry should recognise the potential markets in water and waste treatment, and in monitoring equipment, and conduct the R & D needed to exploit these opportunities, in partnership with Government (DTI and DOE) where appropriate;

(d) Members of the scientific and engineering community, especially NERC, SERC and the universities to which they award grants, have a responsibility for developing basic and strategic research in the freshwater and marine environment and in the engineering required by the water industry.

8.9 We are aware of trends that may increase the fragmentation of effort and create gaps. With continuing pressure to reduce expenditure, including research expenditure, and to improve value for money, funding bodies are examining ever more closely the objectives of their research programmes. For WRC this means close consultation with their membership, primarily the water authorities, to ensure that the programme meets their priorities. DOE is re-examining its programme to see that it meets its precise needs and responsibilities. In its corporate plan, NERC is opting to concentrate its efforts in fewer areas of science. While we recognise the advantages of clear research objectives, and the need to maximise benefits, the trend carries the danger that funders will take an increasingly narrow view of their responsibilities, with the result that research will become excessively compartmentalised. In the Committee's view, the more this process continues the more important it will be that somebody, somewhere, can review the whole field and comment on its shape and balance.

8.10 Any programme of research that is as diverse, and involves as many participants as that in the water field, will inevitably raise questions of co-ordination. We consider, however, that the need is for communication rather than co-ordination in a managerial sense. We do not believe that the case has been made for putting all the

programmes we have examined under a single central Review or Commissioning Board. But we are concerned that there be machinery for interchanging programmes and adjusting them where necessary.

8.11 Steps have been taken in recent years to improve the discussion of research matters between funding bodies. DOE and MAFF exchanged details of related research programmes and collaborate closely in areas of mutual interest. DOE maintains close contacts with WRC, NERC and SERC and, following the House of Lords Select Committee on Science & Technology Report on the water industry, is taking a closer interest in the research programmes of individual water authorities. A jointly-funded post has been created to improve co-ordination of civil engineering research between DOE and SERC. WRC has elaborate arrangements for canvassing the views of their membership on their programme. This liaison is probably one reason why we have found no evidence of unnecessary duplication of research. The weakness in liaison appears to be not in avoiding overlaps, which financial constraints on budgets do much to deter in any case, but in ensuring that the boundaries of the funding agencies' areas of concern actually meet and provide comprehensive coverage. It is our contention that the emphasis of research liaison at this level should be less in the detailed scientific aspects of programmes and more on closing gaps and allocating responsibilities.

8.12 While the working contact between the water authorities and their research organisation, WRC, is close and effective, and that between these authorities and DOE and the research institutions of the NERC is satisfactory, that between the water industry (in its widest sense) and the universities and polytechnics, where much of the more fundamental research of major importance to the long term health of the industry is pursued, is chancy, ad-hoc and largely personal. Steps must be taken to develop a continuing working relationship at national and local levels, and this ought to be an important element of the research liaison mentioned above. Significant contributions to the industry's welfare can be expected from the more rapid application of this research and of existing knowledge. Either SERC or the Committee of Vice-Chancellors and Principals (and the corresponding body for polytechnics) should take the lead for the academic bodies, with the WRC acting for the industry. Permanent liaison should be set up with 'workshop' meetings perhaps annually.

8.13 We have noted elsewhere the formation of groups such as the Nitrate Co-ordination Group and the UK Acid Waters Review Group, and we have been greatly helped by the report of the Coasts and Estuaries Research Review Group. A feature of these committees is the opportunities which they provide for informal co-ordination and multi-disciplinary discussion of particular research topics. They have the merit of covering a small enough theme for there to be genuine community of interest, but a

large enough one to provide useful co-ordination especially if the wider scientific community, including universities and polytechnics active in the more fundamental areas of research, is given the opportunity to participate. We strongly support the continuation of such groups, on a pragmatic basis, in those areas and for such periods as the needs exist. Our special study of sludge dumping at sea suggests that such an approach on the toxicology and ecology of marine organisms and systems would be worthwhile, especially as CERRG no longer exists. We believe it to be important that the existence of these groups is widely known and that their findings are properly disseminated.

8.14 In the absence of the former DOE/NWC Standing Technical Committees, we feel it is necessary to find some alternative means of continuing discussion between Central Government and the water industry. There exist important technical committees on sewers and water mains and process systems but at the moment MPMMG, for example, is one of the few fora in which constructive discussion is possible on monitoring and operational problems associated with the water authorities and RPBs. Successor arrangements to the Standing Technical Committees are still being made, but we doubt whether the scale of activity and the coverage envisaged is sufficient.

8.15 Information on research in the UK is collected periodically for research registers. Water research is among the subjects covered by the Directory of European Environmental Research Projects (ENREP) for which DOE collects information. Research in British Universities is also covered in another register. A Register of Research in the Water Industry produced by WRC was last published in 1980. While such registers may appear essential, experience with the WRC publication is that it is rapidly outdated and rarely used. R&D workers tend to rely on individual contacts, conferences, seminars and general publications. However, there is a need for an up to date research and technology intelligence service to identify and disseminate knowledge on new thinking and successful applications in order to encourage the more direct contacts. WRC is assessing the cost-effectiveness of such an approach in the water treatment area, using newsletters to provide up to date information on contacts, research, application of technology by the utilities and academic work within the universities. The possibilities of linking data collection for ENREP with the annual reporting of water authority research programmes to DOE is being explored and may lead to the production of a more useful register covering the 800-odd projects commissioned by the UK water utilities. We support these efforts to improve the dissemination of information on research.

Future Consideration of Long Term Research

8.16 Our study has shown that the longer term aspects of most areas of research are reasonably well covered but some adjustments are required. The inadequacies that we have identified arise mostly in areas where responsibilities and disciplines are divided, where there are uncertainties about the implications of long term trends, and where the potential benefits of basic or speculative research have been underestimated. We do not consider that our Committee, as currently constituted, is best able to effect the improvements required and **we recommend that it be disbanded.**

8.17 We have identified research which falls within the responsibilities of Government Departments, water undertakers, Research Councils and others but we have stopped short of allocating responsibilities. As stated in 8.7 we are also aware that our recommendations generally concern broad areas of work and specific research proposals need to be developed in the light of the detail of existing work and the availability of funds. Implementation of our recommendations is a matter for all the funding agencies and **we recommend that they should now agree between themselves their responsibilities for each of our proposals and taking account of existing work they should develop and cost specific research plans and implement them.**

8.18 The results of our study have convinced us that there is a need for some simple machinery to facilitate and monitor implementation of our recommendations. **We therefore propose that:**

(a) the Chief Scientist, DOE, chairs a small Water Research Liaison Committee (WRLC) to review implementation;

(b) WRLC comprises one representative of each of the principal organisations responsible for allocating resources and formulating research programmes in this field: DOE, MAFF, WRC, NERC, SERC and the Water Authorities Association;

(c) WRLC meets at least annually to consider short reports prepared by each organisation represented describing actions taken or planned which relate to our recommendations and to prepare a statement summarising subjects requiring further attention.

8.19 We are conscious of the fact that the next 3 or 4 years are likely to see major changes in the water industry. While our current recommendations define the need for long term research in today's circumstances, we consider that it may be necessary for a further review to be carried out in about 4 years' time, to bring our survey up to date. We consider that this, like our present survey, will need to involve people outside the water industry.

MEMBERSHIP OF THE LONG TERM WATER RESEARCH REQUIREMENTS COMMITTEE

Chairman	Dr M W Holdgate	Department of the Environment
Members	Professor R J H Beverton	University of Wales Institute of Science and Technology
	Dr R T Clarke	Freshwater Biological Association, NERC
	Dr M Dart (until March 1985)	Thames Water
	Dr A L Downing	Binnie & Partners
	H Fish	NERC
	M G Healey	Department of the Environment
	H W Hill	Ministry of Agriculture, Fisheries and Food
	Professor P C G Isaac	Consulting Engineer
	R McGillivray (from June 1985)	Scottish Development Department
	E H Nicoll (until May 1985)	Scottish Development Department
	K F Roberts	Wessex Water
	M J Rouse	Water Research Centre
	Dr A J Shuttleworth (from April 1985)	Yorkshire Water
	Dr M Waring	Department of Health and Social Security
Secretary	J F Bonsall	Department of the Environment
	Dr D C Watson (Oct-Nov 1985)	Department of the Environment

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LIST OF ABBREVIATIONS USED IN REPORT

AFRC	Agriculture and Fisheries Research Council
AQC	Analytical quality control
BGS	British Geological Survey
BOD	Biochemical oxygen demand
BPEO	Best practical environmental option
BRE	Building Research Establishment
CERRG	Coasts and Estuaries Research Review Group
DAFS	Department of Agriculture and Fisheries in Scotland
DEn	Department of Energy
DHSS	Department of Health and Social Security
DNA	Deoxyribonucleic acid
DOE	Department of the Environment
DTI	Department of Trade and Industry
EC	European Community
EIFAC	European Inland Fisheries Advisory Committee
ESRC	Economic and Social Research Council
EQO	Environmental quality objectives
EQS	Environmental quality standards
FTLC	Fisheries Technical Liaison Committee (MAFF/WAA)
FBA	Freshwater Biological Association
ICA	Instrumentation, control and automation
LTWRRC	Long Term Water Research Requirements Committee
MAFF	Ministry of Agriculture, Fisheries and Food
MPMMG	Marine Pollution Monitoring Management Group
NCC	Nature Conservancy Council
NERC	Natural Environment Research Council
NFU	National Farmers Union
NWC	National Water Council
OGDs	Other Government Departments
RPB	River Purification Board
SDD	Scottish Development Department
SERC	Science and Engineering Research Council
SNFU	Scottish National Farmers Union
SNG	Substitute natural gas
UK	United Kingdom

UKAWRG	United Kingdom Acid Waters Review Group
WA	Water Authority
WAA	Water Authorities Association
WCo	Water Company
WHO	World Health Organisation
WO	Welsh Office
WRC	Water Research Centre
WRLC	Water Research Liaison Committee