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ROYAL COMMISSION
ON
ENVIRONMENTAL POLLUTION

SIXTEENTH REPORT

To the Queen's Most Excellent Majesty

MAY IT PLEASE YOUR MAJESTY

We, the undersigned Commissioners, having been appointed "to advise on matters, both national and international, concerning the pollution of the environment; on the adequacy of research in this field; and the future possibilities of danger to the environment";

And to enquire into any such matters referred to us by one of Your Majesty's Secretaries of State or by one of Your Majesty's Ministers, or any other such matters on which we ourselves shall deem it expedient to advise:

HUMBLY SUBMIT TO YOUR MAJESTY THE FOLLOWING REPORT.
"Heb ddŵr, heb ddim."
(Without water there is nothing.)

Welsh proverb.
PREFACE

To assist us in our deliberations we invited consultants to prepare reports on aspects of water pollution and its control. Two of these reports are reproduced as appendices to this report. The remainder are available in a separate publication entitled ‘Freshwater Quality: Reports undertaken for the Royal Commission on Environmental Pollution’. It is available from HMSO, separately priced.
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2. Organisations and individuals who contributed to the study
3. Organisational and regulatory arrangements in the UK
4. EC dangerous substances lists and UK Red List
5. The River Tame and the Bedford Ouse – Comparative Case Studies
   (by the Water Research centre)
6. Freshwater and Effluent Quality Monitoring (by the Water Research centre)
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CHAPTER 1

INTRODUCTION

Background to the study
1.1 The United Kingdom is fortunate in being comparatively rich in water resources and is affluent enough to be able to go to considerable lengths both to protect them from pollution and to purify them for public supply. In contrast, much of the world lacks adequate supplies of water for sanitation and for drinking, a problem which is likely to become more severe as the world’s population continues to grow. Cholera and typhoid epidemics occur as a result of polluted drinking water. The World Health Organisation identifies impure drinking water as one of the world’s main causes of child mortality. These issues are an extension of the chronic problems of disparity of natural and material resources between countries; the debate as to the best way for wealthier countries to help the poorer involves ethical, political, social, economic and scientific considerations that are beyond the scope of the present report. They are, however, key elements in a web of interacting global environmental problems that will rightly demand increasing attention.

1.2 In this country, important developments in river pollution control took place in the last century. The widespread introduction of water-closets resulted in a substantial increase in water pollution in major centres of population as raw sewage was piped to rivers where it overwhelmed their capacity to biodegrade the wastes. Michael Faraday, the bicentenary of whose birth was celebrated last year, wrote to the Times in 1855 about the state of the Thames (figure 1.1) and the

Figure 1.1 Comment on the Thames in the 19th century
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FARADAY GIVING HIS CARD TO FATHER THAMES;
And we hope the Dirty Fellow will consult the learned Professor.
Chapter 1

‘Great Stink’ of 1858 forced the closure of Parliament. This latter episode was a factor in the decision to adopt the plans developed by the Victorian engineer, Joseph Bazalgette, whose anniversary was also celebrated last year, to construct a sewerage system in London to intercept the wastes before they reached the river and transfer them to outfalls in the estuary below London. The Royal Commission on Sewage Disposal, which sat from 1898 to 1915, set standards which are still widely referred to today. Current legislation controlling inputs of polluting substances to inland waters follows a direct line of succession from the Rivers Pollution Prevention Act of 1876. Many improvements and refinements have taken place since then, most recently in the Environmental Protection Act 1990 and the Water Act 1989 which, amongst other things, established the National Rivers Authority in England and Wales. The water legislation for England and Wales has since been consolidated, control of water pollution now being dealt with mainly in the Water Resources Act 1991.

1.3 Despite the attention devoted to improving river quality, substantial pollution of inland waters has taken place. The survey of the state of the environment in the Commission’s First Report, in 1971, drew attention to water pollution by sewage, detergents and industrial discharges. Such problems continue and are discussed in later chapters of this report. More recently other sources of pollution have come to prominence, particularly agriculture and diffuse inputs such as acid rain. Concern is also starting to focus on pollution of groundwater, which has been less extensively monitored than surface water.

1.4 Water quality received increasing public attention during the late 1980s, partly generated by the impending privatisation in 1989 of the water industry in England and Wales and partly because of a growing awareness of environmental problems. Drinking water, marine waters and freshwaters all came under scrutiny. In the case of rivers, concerns appeared to be borne out by the results of the 1985 quinquennial river quality survey. This suggested that, in England and Wales, the gradual improvement in river quality that had been recorded in successive surveys for the 20 years up to 1980 had come to a halt. The then water authorities and other commentators drew special attention to a lack of investment in sewage treatment and to pollution stemming from modern, intensive farming practices. The results of the 1990 survey, discussed in paragraphs 1.13–1.17, heighten concerns about river pollution in England and Wales.

1.5 The 1980s also saw water protection policies continuing to develop in the European Community. Previously agreed directives, such as those on drinking water and bathing water, were implemented and discussions took place on new directives, most recently those on urban waste water treatment and nitrate in surface waters. Prior to privatisation of the water industry, the Government announced a major investment programme for the industry, estimated to cost £28 billion in England and Wales over 10 years, partly aiming to meet European Community requirements. Other measures to improve water quality in the UK, including new controls over pollution from agriculture and other sources, have also been taken in recent years. Many of these developments in Government policy were announced during the course of an inquiry in 1986–87 by the House of Commons Select Committee on the Environment into pollution of rivers and estuaries.

Scope of the report

1.6 Pollution of estuaries and coastal waters was considered in the Commission’s Third and Tenth Reports. The Eighth Report considered the effects of oil pollution on the marine environment. We have not reviewed these areas in this report and have restricted our attention to non-marine waters, including groundwaters. The NRA and its counterparts in Scotland and Northern Ireland include all waters below the tidal limits of rivers within their surveys of estuaries rather than in the freshwater river surveys. The DOE’s Harmonised Monitoring Scheme (see chapter 4) includes only waters at or above tidal limits. We have not restricted ourselves so rigidly. In chapter 8, for example, we have drawn on research relating to tidal waters of the Forth and Tees which we consider to be of relevance to freshwater rivers. Many of our conclusions and recommendations are as relevant to waters below tidal limits as they are to non-tidal waters. We have, in addition, been conscious of the importance of rivers as carriers of pollutants into the
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seas. This issue was raised in discussions we held with representatives of the Dutch government. Governments of countries bordering the North Sea have agreed to reduce inputs of dangerous substances, between 1985 and 1995, by 50%. The British government has extended this undertaking to all UK coastal waters. These commitments require reductions from all sources, including loads carried into the sea by way of rivers.

1.7 We have looked widely at problems of freshwater pollution and have considered both surface waters and groundwaters. Our study has been able to build on the report of the Select Committee and to take into account changes that have taken place since, in particular the creation of the National Rivers Authority for England and Wales (appendix 3 describes the organisational arrangements in the UK for the control of water pollution). We have not addressed problems of drinking water except insofar as pollution of surface and groundwaters affects their suitability as sources for abstraction.

1.8 In keeping with our terms of reference, this report concentrates on problems caused by pollution. However, aspects of water quality are inevitably related to variations in quantity and are therefore affected by such matters as rainfall, water abstraction, drainage and flood prevention works. Appendix 5 illustrates this in the context of nitrate concentrations in the Bedford Ouse (paragraph 69). Moreover, as the Commission's First Report pointed out, if demand for water increases, then effluent discharges are likely to increase. This could lead to a deterioration in river quality unless effluent quality were improved, by enhanced treatment, at higher cost. Maintaining and improving river quality can thus become harder and more expensive as demand for water rises. Meeting increased demand can itself be costly and environmentally damaging involving, for example, the flooding of valleys to construct reservoirs. Heavy abstraction can lead to rivers drying up and water levels in aquifers falling. Evidence we received from the Confederation of British Industry drew attention to trends in industry to use less water by greater use of recycled water and other changes in production processes. Such trends are welcome and recommendations we make in chapter 8 on the use of economic instruments should help to encourage them. In chapter 9 we discuss further the relationship between the quantity and quality of water resources and recent proposals and actions by the NRA to maintain a balance between demand and supply.

1.9 Discussions during the course of this study with representatives of both the Dutch and German governments drew our attention to the problems that can arise when major rivers cross national frontiers. Agreed, co-ordinated policies and actions by the countries concerned are essential in such circumstances if quality is to be maintained and improved. This is of crucial importance where countries depend on the rivers as sources of abstraction for drinking water yet have no control over activities upstream which might affect the quality of those sources. The Netherlands retain a 42-day supply of abstracted water from the Rhine at least partly as a security measure in case of pollution incidents. Even within Britain, some pollutants, such as acid rain, have an international aspect. In general, however, as an island, Great Britain has the opportunity to secure through its own efforts the standard of river water quality to which it aspires. Where the United Kingdom does have a land boundary, between Northern Ireland and the Irish Republic, cross-border river flows are minor in comparison with the major European rivers.

The importance of freshwater

1.10 Freshwater is vital for life. Agriculture requires water for livestock, for specialised production and for irrigation of crops. Water is also an essential industrial resource. Many industries require freshwater as a feedstock. It is also used for steam generation and cooling, particularly in power stations. Water is now little used as a direct power source but remains an important source of energy for generating electricity. Inland waterways are still used for commercial transport in some places, though less in Britain than in continental Europe, and are important for many leisure activities. Freshwaters are widely cherished for their natural beauty. They provide many important wildlife habitats, not just for aquatic life forms but also for others that depend wholly or partly on open water or wetland ecosystems. As a result, some rivers and many lakes, pools or other enclosed waters have been designated sites of special scientific interest.
Chapter 1

(SSSIs) and wetland habitat is an important element of many other SSSIs. Outside designated areas freshwaters support varied habitats of nature conservation interest.

1.11 Of particular relevance to this report, freshwaters are the most important medium for receiving, processing and transporting liquid effluents. Estimates by the Water Research centre (WRC) suggest that about 80% by weight of all waste arisings in England and Wales are liquid effluents disposed of partly to seas and estuaries but mainly to rivers. The Commission's First Report pointed out in 1971 that about 13 million cubic metres of water were then supplied every day to homes and industry in England and Wales and that most of this water was returned each day to the river systems in effluent from sewage works and industry. The figure has since risen to about 17 million cubic metres. In comparison, the average daily total flow of rivers into the seas in England and Wales is about 180 million cubic metres. In practice, all significant rivers in the country and even small streams receive effluents, sometimes on a scale which exceeds the dry weather flow of the rivers themselves (see, for example, table 1.1).

<table>
<thead>
<tr>
<th>River</th>
<th>Abstraction point</th>
<th>Effluent as percentage of average river flow</th>
<th>Dry weather river flow*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Ouse</td>
<td>Foxcote</td>
<td>1.9</td>
<td>17.7</td>
</tr>
<tr>
<td>Great Ouse</td>
<td>Clapham</td>
<td>6.8</td>
<td>52.0</td>
</tr>
<tr>
<td>Great Ouse</td>
<td>Offord</td>
<td>12.2</td>
<td>58.3</td>
</tr>
<tr>
<td>Lea</td>
<td>New Gauge</td>
<td>16.5</td>
<td>81.4</td>
</tr>
<tr>
<td>Thames</td>
<td>Swinford</td>
<td>4.6</td>
<td>33.8</td>
</tr>
<tr>
<td>Thames</td>
<td>Sunnymeads</td>
<td>11.9</td>
<td>99.8</td>
</tr>
<tr>
<td>Thames</td>
<td>Staines</td>
<td>12.1</td>
<td>101.4</td>
</tr>
<tr>
<td>Thames</td>
<td>Surbiton</td>
<td>14.4</td>
<td>141.4</td>
</tr>
</tbody>
</table>

* Dry weather river flow is defined as the flow exceeded for 95% of the time.
Effluent percentage can exceed 100% because of reuse of water.

Source: Fawell J.K. et al

1.12 To some degree, rivers have a natural purifying capacity through the action of microorganisms, sunlight and physical aeration. It has become accepted practice to take advantage of this attribute; discharges are commonly permitted within what is perceived to be the assimilative limit of receiving waters. In chapter 9 we discuss this approach and propose that progressively less reliance should be placed on the environment as a mechanism for processing wastes (paragraph 9.41 et seq). Over a period of time, as technology and resources permit, this would require increasingly tight limits on discharges. Meanwhile, the use of rivers to receive polluting effluents carries with it an obligation to consider carefully the nature and degree of treatment needed before discharge, the best location for siting discharges and their timing in order to keep adverse effects to a minimum.

Recent trends in quality

1.13 The necessary degree of care has not always been exercised in the past and some rivers have suffered severely. One of the worst stretches in England is the Mersey Basin, where pollution of the estuary and the waters feeding it are being tackled in a 25 year campaign expected to cost £2.5 billion. Appendix 5, prepared for us by the Water Research centre, describes another heavily
polluted river, the Tame in the West Midlands. In 1958 over 2,000km of rivers and canals in England and Wales were identified as grossly polluted. Some of the worst cases have since been remedied but in 1980 the figure remained at 800km. Changes in definition prevent direct comparisons with more recent figures. The 1980 survey was, however, re-evaluated using a scheme developed by the former National Water Council which has been used for subsequent surveys. It is described in detail in chapter 4. Under this scheme 640km of freshwater rivers and canals in England and Wales were classified as of bad quality (class 4) in 1980, a figure which remained virtually unchanged in the 1985 and 1990 surveys (see box 1.1 and figure 1.2). Rivers and canals classified as of poor quality (class 3) have meanwhile increased from 3,260km in 1980 to 4,022 km in 1990. Some of this increase is due to recalculation of river lengths and some may be due to statistical variability (see paragraph 4.35). It nevertheless seems likely that the past decade has seen a net increase in the length of poor quality rivers and canals in England and Wales.

**BOX 1.1 WATER QUALITY IN ENGLAND AND WALES**

A survey of the quality of rivers, canals and estuaries in England and Wales was carried out in 1990 by the National Rivers Authority (NRA). Such surveys had been carried out in 1958 and quinquennially since 1970. The classification scheme used since 1980 was that developed by the National Water Council (see chapter 4).

The 1990 Survey found that nearly 90% of the length of freshwater rivers and canals was of good or fair quality (see figures 1.2 and 1.5). Many stretches of water had changed quality class since 1985, with 15% being assigned to a lower quality class and 11% to a higher class.

The net deterioration between 1985 and 1990 was 3.6%. Whilst this is subject to statistical uncertainty, the NRA is confident that the true figure lay between 2.1 and 4.3% of river length. Most of the decline was in the best quality waters, especially those in the Thames basin and in Devon and Cornwall.

The NRA attributes the net deterioration to three main factors:

- improved monitoring, giving more accurate results than the 1985 data;
- dry weather in 1990, reducing river flows and hence the dilution of pollutants discharged;
- increased discharges from sewage works, industry and farms.

The survey confirmed the reversal in earlier trends of improvement. From 1958 to 1980 there had been a net improvement; the length of rivers in the poorest quality classes had declined, whilst the length in the best had increased (see figure 1.2).

1.14 At the other end of the scale, the length of unpolluted rivers in England and Wales increased from nearly 25,000km to 28,500km between 1958 and 1970, an increase that may have reflected the greater length of rivers surveyed in 1970. Thereafter, the length of unpolluted rivers remained broadly constant until 1980. On the different classification adopted since 1980, the length of good quality (class 1) rivers fell from 28,000km to just below 27,000km in 1990 despite an increase in the length of rivers surveyed. Within class 1, the length of the best quality rivers (class 1A) declined from 13,830km to 12,400km. As with class 3 some of this apparent change may be due to recalculation of river lengths and to statistical variability. The NRA's report on the 1990 Survey states that some of the decline may also reflect better monitoring, and thus a more accurate assessment of quality in the latest survey, and that the net effect of the dry weather in 1990 was detrimental. After allowing for these factors, the NRA nevertheless concludes that "a
Figure 1.2  Freshwater quality in England and Wales: 1958–1990

![Diagram showing changes in freshwater quality from 1958 to 1990.](image)

*Class 1 comprises the total for classes 1A and 1B

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km</td>
<td>%</td>
<td>km</td>
<td>%</td>
<td>km</td>
<td>%</td>
<td>km</td>
</tr>
<tr>
<td>Unpolluted</td>
<td>24930</td>
<td>72</td>
<td>28500</td>
<td>74</td>
<td>28810</td>
<td>75</td>
<td>28410</td>
</tr>
<tr>
<td>Doubtful</td>
<td>5220</td>
<td>15</td>
<td>6270</td>
<td>17</td>
<td>6770</td>
<td>17</td>
<td>510</td>
</tr>
<tr>
<td>Poor</td>
<td>2270</td>
<td>7</td>
<td>1943</td>
<td>5</td>
<td>1770</td>
<td>5</td>
<td>2000</td>
</tr>
<tr>
<td>Grossly polluted</td>
<td>2250</td>
<td>6</td>
<td>1700</td>
<td>4</td>
<td>1270</td>
<td>3</td>
<td>810</td>
</tr>
<tr>
<td>Total</td>
<td>40630</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: NRA 1990 River quality survey

real net deterioration in river quality has occurred over the last decade. This gives cause for concern. Forecasts made by the former water authorities at the time of the 1985 survey were for a slight improvement in river quality to 1990. Government policy in recent years has been to maintain or improve river quality and in particular to eliminate, over an undefined period, class 4 rivers and reduce steadily class 3. The results of the 1990 survey suggest that, modest though these policy aims may have been, action to secure their achievement has so far been insufficient.

1.15 In Scotland, in contrast, the quinquennial surveys have shown continued improvement during the past decade (see table 1.2 and figure 1.4). 97% of river length is now in class 1 and only 0.1% is in Class 4. The Scottish classification scheme is different from that used in England and Wales, the classes being defined in less detail and with a greater degree of subjectivity (see table 4.3). Direct comparisons with England and Wales are, therefore, not possible. The trend of improvement is nevertheless gratifying and reflects long term efforts that have been made to eliminate gross pollution in rivers such as the Clyde and the Forth. Evidence we received from the Scottish River Purification Boards Association drew attention to the advantages of the separation in Scotland of regulation from operation of sewage works, a separation which has now been
Introduction

Table 1.2

<table>
<thead>
<tr>
<th>Class</th>
<th>1980 km</th>
<th>1985 km</th>
<th>1990 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45,184</td>
<td>45,510</td>
<td>46,111</td>
</tr>
<tr>
<td>2</td>
<td>1,981</td>
<td>1,688</td>
<td>1,177</td>
</tr>
<tr>
<td>3</td>
<td>256</td>
<td>266</td>
<td>233</td>
</tr>
<tr>
<td>4</td>
<td>162</td>
<td>131</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>47,583</td>
<td>47,595</td>
<td>47,591</td>
</tr>
</tbody>
</table>

* * Excludes rivers on islands which were not included in previous surveys (3,142 km Class 1; 4 km Class 2)

Source: Scottish Office Environment Department. Water Quality Survey of Scotland 1990

introduced in England and Wales with the creation of the NRA and which is also proposed for Northern Ireland (see paragraph 1.26). Results of the most recent survey in Northern Ireland were not available at the time of writing. The 1985 survey results are illustrated in figure 1.3.

1.16 Other sources of information about the quality of rivers include the Department of the Environment's Harmonised Monitoring Scheme (see box 4.5) and reports on compliance with European Community directives. No national assessment of quality is currently produced from the harmonised monitoring scheme data nor for the purposes of most directives. However, table 1.3 shows information provided by the Department of the Environment on compliance with the EC's freshwater fish directive. This directive sets standards for the quality of waters designated by member states as capable of supporting healthy fish stocks or capable of doing so within 5 years. In 1984, 3% of designated waters in the UK were recorded as failing to comply with the directive's standards; the report for 1989 recorded a rise in non-compliance to 4.2%. In England and Wales the failure rate was 7.6%. Comparison of lengths in table 1.3 with those in figure 1.2 and table 1.3 reveals that a surprisingly high proportion, over one-quarter, of class 1 rivers have not been designated under the directive, suggesting that they are not considered capable of supporting healthy fish stocks. Earlier this year, the Government designated a further 2,300 km of Scottish waters under the directive. This is welcome but the continuing discrepancy casts doubt on the procedures used for designating waters. We are therefore pleased to record that DOE officials advised us that they intend to review implementation of the directive.

1.17 The NRA discusses in its report of the 1990 river quality survey some of the reasons for

Table 1.3
Compliance with the EC freshwater fish directive

<table>
<thead>
<tr>
<th></th>
<th>designated km</th>
<th>non-complying km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>19,320</td>
<td>1,469</td>
</tr>
<tr>
<td>England and Wales</td>
<td>34,263</td>
<td>741</td>
</tr>
<tr>
<td>Scotland</td>
<td>1,191</td>
<td>77</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>54,774</td>
<td>2,287</td>
</tr>
<tr>
<td>UK</td>
<td>51,000</td>
<td>1,500</td>
</tr>
</tbody>
</table>
changes in river quality. It cites, in particular, improvements at some locations and deteriorations elsewhere in sewage works' effluents, agricultural pollution and industrial effluents. The classification scheme used for the survey concentrates on oxygen and ammonia levels, which are likely to be particularly influenced by sewage discharges and certain types of agricultural pollution. This may partly explain why these sources of pollution receive prominence in the survey report. We set out in chapter 4 our views on ways in which the survey might be made more representative of the state of rivers. Nevertheless, it is clear from the NRA's description of changes in its regions that investment in pollution abatement and greater care in managing potentially polluting processes have brought dividends but that these have been offset by lack of investment elsewhere and by other developments which have resulted in a decline in river quality. Many of the important causes of freshwater pollution are well known and, to some extent, improvement should result from steps taken in recent years, referred to briefly in paragraph 1.5, and from more recent proposals such as those for statutory water quality objectives (see chapter 4). As old pollution problems are alleviated, however, new ones emerge and have to be tackled. New substances are synthesised and subsequently find their way into water. Changes take place in traditional practices, for example in farming, some of which lead to new pollution threats. Advances in monitoring techniques and other scientific developments identify hitherto unrecognised problems. While different solutions will be needed for different problems, we believe that some guiding principles can be applied. We discuss these below under the headings of sustainable use, conflicts of use and impacts on the non-aquatic environment.

Sustainable use of freshwater

1.18 Since water is vital to human survival it is essential to ensure that it is not only able to meet present needs but will also be likely to meet future needs so far as these can be foreseen. This approach, which has been recognised for many years, can be described as the sustainable use of freshwater. Sustainability does not mean going back to an idealised past of pristine waters untouched by human activity, if such a state could be defined. The Prince of Wales has pointed out that an industrialised, densely populated country will inevitably affect the quality of its waters. Responsible stewardship requires, however, that the quantity and quality of water are not reduced to such an extent that future generations are denied opportunities which are available today. We consider that future generations should have access to water resources of a quantity and quality that will allow them no less, and preferably a greater, range of options than is enjoyed today. This is an approach which has much in common with the definition of sustainable development used by the Brundtland Commission, namely 'meeting the needs of the present without compromising the ability of future generations to meet their own needs.'

1.19 Since the needs of future generations cannot be fully known, translating a commitment to the sustainable use of water into practical policies for the present requires difficult judgments. Some broad conclusions can, nevertheless, be developed from the general concept. In particular, some current activities conflict with the concept of sustainability. For example, chapter 5 discusses evidence that groundwater is being polluted in ways that are in practicable terms irreversible; chapter 6 discusses changes in the natural balance of lakes and rivers resulting from inputs of plant nutrients (nitrate and phosphate) which affect the water's ability to sustain biological diversity and to meet human needs; chapter 7 draws attention to the long term consequences for water quality of contamination of land by some industrial and other activities. Although not a pollution matter, chapter 9 discusses briefly abstraction of water from surface and groundwaters at rates which cannot be maintained indefinitely without serious adverse environmental impacts. Policies are therefore needed which will enable uses that are not sustainable to be recognised and which will encourage appropriate responses.

1.20 The main elements of such policies are, first, to develop reliable ways of monitoring the quality of freshwaters and the condition of communities of plants and animals which depend on them. Our recommendations on monitoring are developed in chapter 4 and, for groundwater, in chapter 5. Keeping a close watch on long term movements and unexpected changes will help to draw attention to deteriorations, whether resulting from human activities or not, and point to steps necessary to maintain the sustainability of freshwaters. A downward trend in the quality of water and in the condition of biological communities would be a warning of a worrying potential
lack of sustainability. The apparent net deterioration identified in recent river quality surveys in England and Wales is thus a matter of concern.

1.21 Secondly, plans must be developed to ensure that the required quantity and quality of water resources are maintained. This means managing demands, whether for discharges of pollutants, for abstractions or for other activities, in a way which balances them against the long term needs for water. The authorities which regulate water use need clear plans to ensure that meeting today's demands does not reduce the future availability of the resource. We develop this point in chapter 9.

1.22 Thirdly, processes which give rise to a cumulative long term deterioration of freshwater, such as those referred to in paragraph 1.19, must be brought under firmer control. We develop proposals for this in later chapters.

1.23 Fourthly, the costs of improvements in water quality should be evaluated in relation to benefits, including benefits to future generations. Irreversible deteriorations in water quality may impose especially heavy future costs. We look in chapter 8 at the economic analysis of pollution and outline a charging scheme designed to reinforce the regulation of water quality by increasing the cost of polluting activities.

1.24 Fifthly, a precautionary approach to pollution control should be maintained. The precautionary principle was developed in Germany during the 1970s and has become widely accepted internationally as a basis for environmental policy. Our Twelfth Report contained a discussion of its origins and interpretation, prepared for us by Dr von Moltke. In this country, the Government's White Paper on the Environment\textsuperscript{16}, published in 1990, stated:

'Where there are significant risks of damage to the environment, the Government will be prepared to take precautionary action to limit the use of potentially dangerous materials or the spread of potentially dangerous pollutants, even where scientific knowledge is not conclusive, if the balance of likely costs and benefits justifies it.'

The need to act in the face of uncertainty was discussed in our Tenth Report where we pointed out that 'there will sometimes be a difference between what can be believed with confidence and what in the absence of certainty it is prudent to assume.' This is not at odds with the need to base policy on sound science nor with the importance of considering costs and benefits before taking action. Rather, it recognises that evaluations of environmental impacts and of economic costs and benefits are often subject to considerable uncertainty. Those responsible for the well-being of the public and the protection of the environment need to have regard to the possible as well as the proven risks of damage, particularly damage that might be irreversible or disproportionately expensive to remedy.

Conflict management

1.25 Freshwaters have many uses; a recurring theme that ran through the evidence we received for this report was the extent to which these uses can be in conflict with each other. An obvious potential incompatibility is between the use of a river for the discharge of sewage works' effluents and abstraction for domestic use downstream of the discharge. Chapter 7 discusses the conflict between the discharge of effluent from sewage works and use of a river for swimming and other water sports involving immersion. Many other examples were illustrated in the evidence we received, including some that are problems of water quantity rather than quality, such as the conflict between abstraction of water for public supply and maintaining adequate water levels for nature conservation, angling or boating (see chapter 9).

1.26 Resolving such conflicts is an essential part of the process of controlling water pollution and, more generally, of managing water resources. It is an area where competing interest groups may take different views and where value judgments may have to be applied. A framework for making such judgments must incorporate three elements: rational criteria, public involvement
Chapter 1

and proper accountability. In the UK over the past 20 years a system of water quality objectives has been developed which enables some competing demands to be evaluated. Under present legislation, the setting of water quality objectives will become a statutory process involving public consultation, a process which we discuss further in chapter 4. With the establishment of the NRA, the clearer accountability for water quality that exists in Scotland has been introduced into England and Wales. In Northern Ireland, it is planned to transfer in 1993 the Water Service of the Department of the Environment to a Government owned company whose discharges will be regulated by the Department. These developments establish the essential elements of an acceptable framework for judging between environmental needs and other requirements. Statutory quality objectives will be at the heart of this process and economic concepts, such as cost benefit analysis, will have an important role to play. We develop these thoughts further in chapters 4, 8 and 9.

The non-aquatic environment

1.27 This report concentrates on the single environmental medium of water. The Royal Commission has long been concerned, however, to look at the environment as a whole. We explored this issue in some detail in our Twelfth Report which developed the concept of the best practicable environmental option (BPEO). It is important to retain this perspective when discussing water pollution. Measures to protect water quality might have adverse side effects on other parts of the environment. Equally, measures to protect land or air should be assessed for their potential impact on water quality.

1.28 The importance of this perspective is illustrated by the problems of protecting groundwater, discussed in more detail in chapter 5. An important threat to groundwater can be the toxic, liquid effluent that can leach out of landfill sites; disposal of wastes to land can thus lead to pollution of aquifers. Another example is discussed in chapter 6, which describes the deterioration of rivers and lakes when acid emissions to the atmosphere are deposited onto water catchments. In contrast, sewage treatment works reduce the polluting impact of the wastes they receive, to the benefit of receiving waters, but generate large volumes of sludge which pose a disposal problem of their own. The Government has recognised the cross-media implications of sludge disposal and has published a BPEO guide addressing the issues.

1.29 Taking account of pollution of the whole environment requires a wide ranging assessment of effects and may be difficult to achieve consistently. It does, however, indicate that a commitment to the achievement of the best practicable environmental option should be a cornerstone of water policy. We regard the measures in the 1990 Environmental Protection Act for securing integrated pollution control as a useful step towards achieving BPEO for a limited but important range of polluting processes. The wider task of introducing BPEO into the policy framework, for example by taking full account of implications for other environmental media in setting statutory water quality objectives, will be difficult.

1.30 A potentially important step towards a more integrated approach to the environment was signalled recently by the publication of Government proposals to establish Environment Agencies for England and Wales and for Scotland. We indicated our support for these developments and offered our views on the best ways to establish the agencies in our responses to the Government’s consultative papers. At the time of writing, the outcome of the consultation processes had not been announced. We have therefore referred throughout this report to the regulatory agencies as they currently exist (see appendix 3). Recommendations addressed to these agencies should be capable of straightforward translation to any successor bodies.

Structure of the report

1.31 In subsequent chapters we address the major issues that have emerged from our inquiries. Chapters 2 and 3 provide background material for the later discussion. Chapter 4 looks at the monitoring and assessment of freshwater quality and objectives for its management. Chapters 5, 6 and 7 describe some important pollution problems including groundwater pollution,
eutrophication, discharge of effluents and agricultural pollution. Chapter 8 is devoted to a discussion of the application of economic principles to the improvement of water quality, including the use of economic instruments, a subject which the Commission first addressed in its Third Report, on pollution of estuaries and coastal waters. We believe that economic aspects are now rightly assuming a higher priority in the consideration of environmental problems. Chapter 9 presents some thoughts and recommendations about policy and planning for water quality which are of more general applicability than those in previous chapters. A summary of the report including all the recommendations is at chapter 10. To assist us with our study, we commissioned from consultants reports on relevant topics, to which we refer at appropriate points in the text. Two are reproduced in full at appendices 5 and 6. The others are contained in a separately published volume.22.
CHAPTER 2
CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF FRESHWATERS

Introduction
2.1 This chapter describes the natural factors which influence the chemical and biological characteristics of rivers, lakes and other surface freshwaters. Factors which determine the quality of groundwater are described in chapter 5. Where groundwater contributes a high proportion of the base flow of rivers, the quality and quantity of groundwater will affect their characteristics.

2.2 Water is one of few inorganic substances that occur in a liquid state at the temperatures and pressures which obtain for most of the year at sea level in temperate latitudes. It was present on earth long before any form of life existed. Its physico-chemical properties have influenced the processes involved in the evolution and survival of living organisms. The physical properties of water (for example its capacity to conduct heat, its transparency to light, its high surface tension and the fact that water is at its maximum density at 4°C) are of particular significance in this respect.

2.3 Of the vast amount of water which occurs on earth, only about 0.5% is liquid freshwater; of that, less than a quarter is at the surface, the remainder being groundwater. These figures exclude underground water at depths greater than several hundred metres, much of it salt water which was incorporated into sediments when they were buried beneath the sea.

The water cycle
2.4 The total amount of water on earth remains virtually constant. Water is transferred from one place to another, and from one state to another, in what is referred to as the hydrological or water cycle (see figure 2.1). The main processes of water transfer are precipitation and evaporation. The amount of water involved globally in each of these processes is estimated to be about 500,000 cubic kilometres a year. The oceans account for about 85% of the évaporation but receive only about 80% of the precipitation. The net transfer of water from oceans to land in precipitation is largely balanced by the run-off of surface waters from land to sea in rivers.

2.5 Water is taken up by living organisms, of whose total mass it constitutes a very great proportion, and is released from them in the processes of respiration, transpiration and excretion. The release or uptake of water which occurs as the result of metabolic processes, in the decomposition of dead plant and animal material, in the process of combustion (for example of hydrocarbons) or during electrical storms, contributes only marginally to the overall cycle.

Water availability
2.6 Precipitation is highly variable in space and time; in many parts of the world there are water shortages and droughts. Major changes in the distribution and amounts of precipitation, evaporation and transpiration have occurred in the past, and may do so again, as concomitants of climate change.

2.7 In Europe, annual precipitation varies between 150mm and 5,000mm, these extremes being found only in small areas. Moisture deficits occur in the drier southern regions of the continent. The UK, with which this report is most concerned, is in the region of moisture surplus. It has a maritime climate, with an annual average rainfall of about 1,000mm, ranging from an annual average of 600mm in the drier eastern counties in the south of England to 2,500mm in the northern and western uplands. There is a marked rainfall gradient from west to east (see figure 2.2a).
Figure 2.1 The water cycle
Chapter 2

Most of this rain finds its way into rivers, streams, lochs and lakes, or, where the surface is underlain by permeable rocks, percolates into aquifers to remain for a time as groundwater. Most European lakes are in areas which were glaciated between 2.5 million and 10,000 years ago. In the British Isles these occur mainly in Scotland, Northern England and Ireland. UK lakes are small by European standards (table 2.1) and the largest UK rivers are smaller and have lower flow rates and residence times than major rivers elsewhere in Europe (see table 2.2).

2.8 The distribution of water demand reflects the location of major centres of population and industry (see figure 2.2b) and the requirements of agriculture. Major areas of demand in the UK are in central, southern and eastern England. Where needs cannot be met locally, the water industry has developed a system of water management for the purpose of supplying water of adequate quality in spite of this imbalance of supply and demand.

Natural chemical characteristics of surface waters

2.9 Gases and other soluble substances in the atmosphere are dissolved by rain, which also washes out particulate material. Rain is naturally somewhat acidic (pH 5.6), largely because it contains carbonic acid, derived from dissolved carbon dioxide. Some rain falls directly into rivers, lakes and streams, but more falls onto land. As rainwater flows over or through the ground and into waterbodies, minerals and other substances are dissolved. Hard water is rich in calcium and magnesium salts, particularly bicarbonates, chlorides and sulphates, and tends to be alkaline. Organic compounds, such as the humic acids which result from the microbial degradation of plant material, also dissolve in water as it runs through the soil. Soft waters with high concentrations of humic acids are brown in colour and are usually acidic (see chapter 6).

2.10 Dissolved gases, particularly oxygen, which has a low solubility in water, are of critical importance to the aquatic environment. Oxygen from the atmosphere dissolves in water at a rate that depends largely on the movement and temperature of the water. Gently-moving waters gain oxygen slowly but water oxygenates rapidly at weirs and in other turbulent stretches of rivers. Oxygen is produced by aquatic plants in the presence of sunlight. It is consumed by freshwater organisms, including micro-organisms, in the process of respiration (see paragraph 3.6). As water temperature increases, the respiration rate of aquatic organisms increases but the solubility of oxygen decreases.

2.11 There are marked differences in the chemical and biological characteristics of upland and lowland waters. Upland rivers and streams tend to be fast-flowing, usually contain few nutrients and are often deficient in minerals such as calcium and magnesium, reflecting the geology of their catchments. Waters from peaty catchments often contain iron, aluminium and manganese and relatively high concentrations of humic substances. Many UK rivers originate as fast-flowing upland streams but adopt the characteristics of slower-flowing lowland rivers as they approach the sea. Lowland waters often contain an admixture of polluted surface run-off and effluents from sewage treatment works and other sources. Even when unpolluted, they tend to have a higher mineral and nutrient content than upland waters and may be turbid as a consequence of the large amount of suspended solids they contain.

Biological characteristics of surface waters

2.12 Green plants, including algae, make use of light energy to convert carbon dioxide to organic substances in the process known as photosynthesis. Energy in the form of food passes from green plants (the primary producers) to herbivorous animals (primary consumers) when the plants are eaten, and subsequently to carnivores (secondary consumers) which prey on other animals. The interactions between these trophic levels can be complex and are sometimes described as a 'food web'. Energy is recycled when excreta and dead organisms are broken down by bacteria and fungi (decomposers).

2.13 The biological characteristics of freshwater are, to a great extent, determined by its physical and chemical properties. Water velocity is probably the most influential factor. The
Figure 2.2 Precipitation and population maps of Great Britain

(a) Average annual precipitation (mm) in Great Britain, 1986–1988

(b) Population distribution of Great Britain, 1971

Reproduced by kind permission of Drs. Dore, Choularton (UMIST) and Fowler (ITE).

Chapter 2

biological communities of the still waters of smaller lakes, ponds and canals, differ from those of the flowing waters of rivers and streams. As the flow rate of a river decreases from source to mouth, the nature of the biota also changes.

2.14 A number of ecologically important physical and chemical factors in river water change during its course towards the river estuary. These changes are most pronounced in long rivers which rise in upland areas, such as the Severn, and least pronounced in short groundwater-fed rivers rising in lowland areas, for example the Lambourn in Wiltshire.

Water velocity generally declines from source to mouth, as the width of the channel increases and the gradient of the bed decreases. However, since gradient does not decline uniformly and the bed may sometimes narrow, there may be some slower-flowing sections in the upper reaches and some faster-flowing sections in the lower reaches.

The substrate type is determined largely by surrounding geology and water velocity. In the fast-flowing headwaters, cobbles, pebbles and gravels tend to dominate and the continual scouring of the river bed prevents the deposition of finer sediment. The slower currents of the lower reaches allow the deposition of suspended particulates as sand, silt or mud.

The temperature of the water usually increases from headwater to estuary. This increase tends to be greatest in rivers rising in upland areas.

The turbulent and shallow waters of fast-flowing rivers are usually well oxygenated and, where the nature of the substrate permits the free passage of water, the interstices of the river bed also contain oxygenated water. As water velocity declines and depth increases, the potential for oxygenation decreases and there is less dissolved oxygen in both water and substrate. The accumulation of fine sediment can also inhibit oxygenation of the substrate.

In upland regions, streams often originate in the run-off from near-surface bedrock or from relatively impermeable overlying soils. These waters are usually nutrient-poor. As a river progresses downstream over deeper and more permeable soils the dissolved nutrient load gradually increases.

2.15 The range of conditions which aquatic organisms can tolerate largely determines their distribution in a water body. Although there is a continuum of change along the length of a river, it is often possible to distinguish a number of zones, each with a characteristic fauna and flora suited to the physical and chemical qualities of the water (see box 2.1).

2.16 The biota of standing waters are strongly influenced by nutrient availability and water stratification. Lakes which contain low levels of available nutrients and support only limited phytoplankton and macrophyte growth are termed oligotrophic. They are often in upland areas where the soils are poor in minerals such as calcium and magnesium, are usually cold and sometimes deep. Wind-blown material may provide most of the nutrients in the lake. The water in oligotrophic lakes can be very clear because of the lack of phytoplankton. Submerged macrophytes may be present, such as bladderwort and water lobelia, which are adapted to low nutrient levels and can thrive in deep water if there is sufficient light. Trout are the dominant fish. Some fish, such as the arctic char, are restricted to upland oligotrophic lakes. The term 'ultra oligotrophic' is sometimes applied to the most nutrient impoverished lakes.

2.17 Mesotrophic lakes contain more nutrients than oligotrophic lakes. They usually support moderate levels of plant growth and a thriving community of invertebrates and fish.

2.18 The water of eutrophic lakes contains high concentrations of nutrients and high levels of plant growth. They tend to be shallow and warm and are often located in lowland areas. Phytoplankton may proliferate to such an extent that blooms are formed from time to time, causing low night-time oxygen concentrations. Further depletion of oxygen occurs when the blooms collapse, leaving a mass of decomposing organisms. Such conditions can adversely affect fish and invertebrate populations. The blooms themselves allow little light to reach submerged plants and the latter may die. In hypertrophic lakes, which contain an excess of nutrients, the ecological balance is disturbed as algal blooms and anoxic conditions predominate. The detrimental effects of excess nutrients on the environment are discussed in chapter 6.
Plate 1  Aerial view of the river Adur, Sussex.

Photograph by courtesy of Sealand Aerial Photography.
Plate 2  River Wharfe near Buckden, Yorkshire – a class 1A river.
Photograph by courtesy of Robert Brook/Environmental Picture Library.

Plate 3  Dead trout. Pollution of a tributary of the river Stour by farm discharge.
Photograph by courtesy of Ronald Toms/Oxford Scientific Films.
Plate 4  Confluence of two streams, one bearing sediment resulting from ploughing prior to afforestation.
Photograph by courtesy of Dr Paul Carling/Institute of Freshwater Ecology.

Plate 5  Litter at Allington Lock on the river Medway, Kent.
Photograph by courtesy of Medway River Project.
Plate 6  The trout zone.

Photograph by courtesy of Professor John Lawton/NERC Centre for Population Biology, Imperial College.

Plate 7  The bream zone.

Photograph by courtesy of Professor John Lawton/NERC Centre for Population Biology, Imperial College.
2.19 In shallow lakes, the wind ensures thorough mixing of the water. In deep lakes, wind mixing is less effective and strong solar heating of the surface may create temperature and density gradients in the water column. A stable boundary, the thermocline, appears at the limit of vertical mixing, separating warmer, less dense upper waters (epilimnion) from the colder, denser lower waters (hypolimnion). This phenomenon, termed thermal stratification, has an important effect on the biological character of the waterbody.

2.20 Most phytoplankton growth occurs in the epilimnion, where the water is warm and light intensity is high. Dead plankton and other organic remains sink below the thermocline and collect on the lake bed. Decomposition of this material leads to nutrient release and oxygen depletion. The consumed oxygen is not readily replaced, for there is little interaction with the well-oxygenated surface water across the thermocline. Water in the hypolimnion is therefore nutrient-rich and oxygen-depleted. Sediments and overlying water may become anoxic, with adverse
### Table 2.1
Sizes of some European lakes

<table>
<thead>
<tr>
<th>LAKE</th>
<th>Area (km²)</th>
<th>Volume (million m³)</th>
<th>Maximum depth (m)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geneva</td>
<td>581</td>
<td>90,000</td>
<td>310</td>
<td>N</td>
</tr>
<tr>
<td>Constance</td>
<td>541</td>
<td>48,450</td>
<td>252</td>
<td>N</td>
</tr>
<tr>
<td>Lough Neagh</td>
<td>385</td>
<td>364</td>
<td>30</td>
<td>N</td>
</tr>
<tr>
<td>Como</td>
<td>146</td>
<td>22,483</td>
<td>410</td>
<td>N</td>
</tr>
<tr>
<td>Zurich</td>
<td>88</td>
<td>3,907</td>
<td>143</td>
<td>N</td>
</tr>
<tr>
<td>Loch Lomond</td>
<td>71</td>
<td>2,628</td>
<td>190</td>
<td>N</td>
</tr>
<tr>
<td>Loch Erich</td>
<td>23</td>
<td>1,307</td>
<td>164</td>
<td>R</td>
</tr>
<tr>
<td>Windermere</td>
<td>15</td>
<td>315</td>
<td>64</td>
<td>N</td>
</tr>
<tr>
<td>Rutland Water</td>
<td>13</td>
<td>130</td>
<td>7</td>
<td>M</td>
</tr>
<tr>
<td>Grafham Water</td>
<td>6</td>
<td>1</td>
<td>20</td>
<td>M</td>
</tr>
<tr>
<td>Derwent Water</td>
<td>5</td>
<td>3</td>
<td>22</td>
<td>N</td>
</tr>
<tr>
<td>Llyn Clywedog</td>
<td>2</td>
<td>50</td>
<td>55</td>
<td>M</td>
</tr>
<tr>
<td>Loch Doon</td>
<td>1</td>
<td>43</td>
<td>31</td>
<td>M</td>
</tr>
</tbody>
</table>

NOTES:  
N = natural lake or loch  
M = man-made reservoir  
R = regulated loch or lake.

### Table 2.2
Sizes of some European rivers

<table>
<thead>
<tr>
<th>RIVER</th>
<th>LENGTH¹ (km)</th>
<th>MEAN FLOW² (m³/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volga</td>
<td>3,690</td>
<td>8,000</td>
</tr>
<tr>
<td>Danube</td>
<td>2,850</td>
<td>7,000</td>
</tr>
<tr>
<td>Rhine</td>
<td>1,320</td>
<td>2,000</td>
</tr>
<tr>
<td>Loire</td>
<td>1,012</td>
<td>6,500</td>
</tr>
<tr>
<td>Rhone</td>
<td>800</td>
<td>2,000</td>
</tr>
<tr>
<td>Severn</td>
<td>345</td>
<td>86</td>
</tr>
<tr>
<td>Thames</td>
<td>328</td>
<td>67</td>
</tr>
<tr>
<td>Trent</td>
<td>274</td>
<td>93</td>
</tr>
<tr>
<td>Great Ouse</td>
<td>251</td>
<td>16</td>
</tr>
<tr>
<td>Wye</td>
<td>190</td>
<td>72</td>
</tr>
<tr>
<td>Tay</td>
<td>185</td>
<td>175</td>
</tr>
<tr>
<td>Dee</td>
<td>163</td>
<td>35</td>
</tr>
<tr>
<td>Clyde</td>
<td>130</td>
<td>46</td>
</tr>
<tr>
<td>Exe</td>
<td>106</td>
<td>17</td>
</tr>
<tr>
<td>Tyne</td>
<td>100</td>
<td>48</td>
</tr>
<tr>
<td>Forth</td>
<td>89</td>
<td>51</td>
</tr>
<tr>
<td>Great Stour</td>
<td>64</td>
<td>3</td>
</tr>
<tr>
<td>Itchen</td>
<td>62</td>
<td>6</td>
</tr>
</tbody>
</table>

NOTES:  
1. The length is the distance (estimated where necessary) from the source to the mouth.  
2. Flow rates are measured in cubic metres/second (m³/sec) at the tidal limit. Where there is no gauging station close to the tidal limit, the figure is an estimate.
consequences for fish and invertebrates (see, for example, box 6.3 on the arctic charr). In the autumn, when the epilimnion cools and strong winds disturb the surface, the thermocline breaks down and the waterbody becomes fully mixed. This phenomenon, termed the autumn overturn, brings nutrient-rich water into the surface layer.

2.21 Stratification of eutrophic or hypertrophic waterbodies poses problems when water is abstracted for public supply. Water from the epilimnion may contain high concentrations of algae which can block filters, while that from the hypolimnion may be tainted by the products of anaerobic degradation and may contain iron, manganese and aluminium. When abstracted water is chlorinated, some algal products yield potentially harmful halogenated hydrocarbons, such as the trihalomethanes; high concentrations of these substances have been recorded in supplies originating from eutrophic waters.
CHAPTER 3
THE IMPACT OF POLLUTION AND WATER USE

Introduction
3.1 The flow of water is altered by many human activities. Some activities, such as the construction of canals and reservoirs, flood protection works and drainage schemes, interfere with the flow directly. The growth of towns and cities which cannot meet their water requirements from local sources has led to major schemes to transfer water from one catchment to another. Parts of East Anglia are habitable and agriculturally productive only as a result of long established drainage and flood prevention works. Because the whole land surface provides the catchment for surface waters, any activity on land can affect both the quantity and quality of local water resources. Urban development, for example, can be a source of pollution and, as a result of rapid drainage from paved surfaces with little infiltration into the ground, may exacerbate flooding problems.

Water demand
3.2 Impoundments for abstraction, water transfer schemes and changes in the quality of water returned after use may all profoundly affect available water resources. Figure 3.1 shows the volume of licensed water abstractions in England and Wales in 1987. The figures include the substantial abstraction of water, mainly for cooling, by the then Central Electricity Generating Board, most of which was returned to rivers with very little loss or contamination but at a higher temperature. In general, water abstraction has decreased during the past decade, with changes in the manufacturing industry contributing most to this decline, as water recycling has increased and some large industrial abstractors closed. There has been a small but steady increase in the amount of water used in agriculture and for public supply.

3.3 Although total water abstraction has decreased, some parts of the south and east of Britain have experienced increases in demand coinciding with drier than average weather conditions, a combination which has led to water shortages. The National Rivers Authority (NRA) and water supply companies are considering ways in which these shortages could be eased. These include metering of domestic supplies to encourage economy of use and inter-catchment water transfer schemes. Leakage from water distribution and supply systems can amount to 30% or more of the water supplied; water companies are working to reduce losses through mains rehabilitation programmes. It has been estimated that as much as one third of the recharge water for the Birmingham aquifer may come from leaking water mains1.

Sources of freshwater pollution
3.4 Sources of pollution are often categorised as point sources or diffuse sources. Point sources are discrete and usually easily identified; they include effluent pipes from industrial sites and sewage treatment works. Most pollution control legislation, including the system of discharge consents, is concerned with pollution from point sources. Diffuse inputs include pollution from aerial deposition and surface run-off from land. In most cases the only practical way to control diffuse pollution is to regulate the activities which may give rise to the pollution. The recent designation of Nitrate Sensitive Areas (paragraphs 7.132 et seq.), aims to reduce the loss of nitrate from land to surface and groundwater by means of changes in farming practices. Some pollution sources, such as contaminated land, do not fall clearly into either the diffuse or point source category. In these cases there may be neither a clearly defined discharge nor a continuing activity which can be regulated in order to control the pollution. Appendix 5 illustrates all three types of pollution in the context of case studies of the Tame and Bedford Ouse.
Impact of Pollution

Figure 3.1 Licensed abstractions of groundwater and surface water listed by purpose for England and Wales (1987)

![Pie chart showing licensed abstractions by purpose]

- Water supply: 17,244
- Spray irrigation: 102
- Industry: 3,712
- Agriculture: 122
- CEGB: 4,578
- Fish farming and watercress: 1,089

Units: Thousands of cubic metres/day.

Notes: Many of the individual quantities which contribute to the total figures are estimated. They vary only slightly from year to year. The data refer only to licensed abstractions. When the data were compiled, abstraction licences were not required for watercress beds or the majority of fish farms. Minor agricultural abstractions were also exempt.


The impact of aquatic pollutants

3.5 The effects of pollutants on freshwater depend on their chemical, physical and biological properties, their concentrations and the duration of exposure. Some pollutants are biodegradable but can affect aquatic life indirectly because their breakdown depletes the water of oxygen (see paragraph 3.6); frequent or lengthy episodes of oxygen depletion can produce long-lasting harm. Other pollutants may be toxic or carcinogenic; those which give rise to greatest concern are either resistant to degradation or able to accumulate in organisms or both. Examples include heavy metals (which bioaccumulate) and certain organic pesticides (often both persistent and bioaccumulative). The toxicity of substances may, however, be modified by other substances in the water and by such factors as pH, water hardness and temperature. For instance, the toxicity to fish, especially salmonids, of many heavy metals is inversely related to water hardness. Some ways in which pollutants affect sectors of the aquatic biological community or the community as a whole, or in which they may restrict the uses to which the affected water may be put, are described briefly below. Others are discussed in more detail in later chapters of this report.

Microbial communities

3.6 Microbes (bacteria and other simple microscopic organisms) are important members of the biological community, largely responsible for the decomposition of organic materials and the consequent recycling of nutrients. They give a waterbody the capacity for self-purification. In the process of decomposition, however, they consume oxygen, thereby limiting the amount available to other aquatic biota, such as fish and invertebrates. Discharges of large quantities of organic pollutants, for example in sewage, may therefore lead to the suffocation of aquatic organisms.
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Some pollutants are toxic to microbial communities and can, as a consequence, inhibit decomposition of organic material and reduce the water's capacity for self-purification.

Algae and higher plants

3.7 Aquatic plants, such as water buttercup, Canadian pond weed and water milfoil, are important sources of oxygen and food, provide valuable habitats for freshwater animals and help to stabilise stream or river banks. Their loss or damage, for example by herbicides, can be detrimental to the aquatic environment.

3.8 The enrichment of freshwaters with plant nutrients, especially phosphorus, stimulates plant growth but in excess can lead to intense algal blooms and the choking of rivers and lakes by rooted plants. Although this abundant biomass may provide additional food and habitat for weed-dwelling organisms, it can adversely affect fish and invertebrates, as described in paragraph 2.18.

Invertebrates

3.9 Invertebrates can be harmed by exposure to pollutants and by the deoxygenation of sediments that results from chronic organic contamination. Such conditions may be found downstream of sewage treatment works discharges, of farms where livestock waste stores are leaking or overflowing and of fish farm. In extreme cases, all but the most tolerant organisms, such as chironomid larvae and some oligochaete worms, may be killed. Pesticides, particularly insecticides and molluscicides, can also have deleterious effects on aquatic invertebrates, as can heavy metals.

Fish

3.10 The death of fish in a river is often the first sign of a pollution incident. Deoxygenation of the water is the usual cause of death. Fish are also adversely affected by pollutants such as ammonia, which is almost always present in sewage and agricultural effluents, and by spillages of toxic chemicals. The death of aquatic invertebrates from pollution incidents also affects fish, by reducing their food supply. Low oxygen levels represent a barrier to the passage of migratory fish; a polluted estuary can deter fish from entering a river to spawn in the unpolluted headwaters. The breeding of salmonid species may also be impaired by the siltation of spawning areas, which reduces the flow of oxygen to the buried eggs.

3.11 Aluminium, especially in its soluble ionic form, is lethal to fish at low concentrations. Increases in levels of dissolved aluminium ions occur in poorly buffered upland waters when acidic run-off flushes out soil-bound aluminium. Fish kills are common under these conditions. Sustained exposure to sublethal levels of persistent organic chemicals, such as organochlorine pesticides and polychlorinated biphenyls (PCBs), and to heavy metals, results in their accumulation in fish tissues, leading to reductions in both growth and reproductive success and eventually to death.

3.12 A recent survey by the Game Conservancy Trust investigated the impact on wild trout of overfishing and environmental degradation in the British Isles. Figure 3.2 is a diagrammatic representation of the major aspects of trout habitat degradation emerging from the study. The study concluded that, as a consequence of this environmental damage or overfishing or both, the vast majority of lowland trout fisheries in the British Isles now rely on stocking to provide fish for angling (see figure 3.3).

Predatory birds and mammals

3.13 Being at or near the top of the aquatic food chain, birds and mammals are particularly vulnerable to the bioaccumulation of persistent compounds. The loss or decline in numbers of otters from much of lowland Britain has been linked to tissue burdens of persistent pesticides. Shortage of invertebrate and fish prey can have a major impact on bird and mammal populations. The decline of dippers in Wales is believed to be associated with the effects of acidification on streams and rivers which has reduced the availability of food for nestlings.
BOX 3.1  BOD, COD AND TOC

Biochemical Oxygen Demand (BOD)
BOD is a measure of the oxygen used by micro-organisms to break down organic molecules. It is the most widely used measure of oxygen demand and of the polluting potential of effluents. BOD is normally determined by comparing the dissolved oxygen in a water sample with that of an identical sample kept in the dark at 20°C for 5 days. Darkness prevents the production of oxygen by photosynthetic organisms.

The detection limit for BOD is 2 mg/l. Low values may be the result of extremes of pH or the presence of substances, such as heavy metals, chlorine, cyanide, phenols and pesticides which can inhibit the action of the micro-organisms. High BOD values can be the result of algal respiration, of the oxygen demand that occurs when algal cells die and are metabolised, or of the oxidation of ammonia or hydrogen sulphide. Most of these problems can be eliminated by diluting and filtering the sample, and adjusting its pH. The BOD test was modified in the late 1970s to inhibit the oxidation of ammonia in the sample and is now usually referred to as the inhibited BOD(15) test.

Chemical Oxygen Demand (COD)
COD is calculated from the amount of potassium dichromate (the oxidant most commonly used) required to oxidise the organic material in a water sample, following the removal of inorganic material by physical and chemical methods. Other chemicals may be added to catalyse oxidation and to bind chloride ions which can interfere with the reaction.

The COD test does not differentiate between biodegradable and non-biodegradable organic substances. It has the advantage of being simple, requires no expensive instrumentation and can be carried out relatively quickly. The limit of detection is 5 mg/l. A close correlation between COD and BOD is unlikely except where the effluent or river water has a very consistent composition.

Total Organic Carbon (TOC)
Commercial instruments are available for the determination of the Total Organic Carbon (TOC) content of a water sample. Their objective is the direct or indirect measurement of dissolved organic carbon by its complete oxidation to carbon dioxide. Some instruments use a high temperature (950°C) catalytic oxidation, others use a cold oxidation with persulphate under intense UV irradiation. Inorganic carbon is usually removed prior to analysis. A limit of detection of 1 mg/l of carbon is claimed for the high temperature analysis and 0.2 mg/l for the low temperature technique, but differences in the results obtained using different instruments have given cause for concern. TOC instrumentation is relatively expensive but the determination is fast and convenient. Like COD, TOC does not distinguish between biodegradable and non-biodegradable material and does not necessarily correlate with BOD.

Relationship between BOD, COD and TOC
Neither BOD nor COD values represent the true oxygen demand, which can only be assessed by consideration of several determinands. The TOC test is similar to the COD test in that each involves an almost complete oxidation of the organic material present in the water sample. The two measures are therefore closely correlated. However, while the COD value represents the oxygen required to bring about that oxidation, the TOC is a measure of the carbon present in the organic molecules.

3.14 The ingestion of lead weights used by anglers has caused poisoning of water birds, notably swans. Recent action by the Government, following a recommendation by the Royal Commission in its Ninth Report, 'Lead in the Environment', to restrict the sale of lead for weighting lines, has resulted in lower mortalities but lead shot, especially at wildfowling sites, and discarded fishing hooks and lines remain a hazard to all water birds.

Human health
3.15 The pollution of water used as a source for public supply is a potential threat to public health. Many chemicals used in industry and agriculture find their way into waterbodies. Legally enforceable maximum admissible concentrations in drinking water have been set for some of
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Figure 3.2 Areas and causes of trout habitat degradation in the United Kingdom

Source: Dr. Nick Giles/Game Conservancy Trust
Impact of Pollution

Figure 3.3  Extent of stocking of formerly wild fisheries with farmed brown trout in the United Kingdom

Source: Dr. Nick Giles/Game Conservancy Trust
Chapter 3

these chemicals under the Water Supply (Water Quality) Regulations 1989. The Regulations include a general requirement to ensure that drinking water does not contain any element, substance or organism, alone or in combination, at a concentration or value which could be detrimental to public health. Water treatment for public supply invariably includes a disinfection stage for the destruction of bacterial and viral pathogens. Outbreaks of cryptosporidiosis have demonstrated that conventional treatment is not always enough to guarantee that drinking water will be free of pathogens. Pathogens in water can also be a hazard to participants in water-based recreation and to those working on fish farms and in other situations that bring them into close contact with contaminated water.

Effects on water required for abstraction

3.16 The efficacy and cost of water treatment, whether for public supply or for private industry, are substantially influenced by the presence of organic substances, suspended solids and algae and by variations in pH and other characteristics. Many industries, for example those producing beverages, are as sensitive as the water industry to the presence in water of potentially hazardous contaminants or of substances that can affect the taste, smell or appearance of their product. Fish farming requires good quality water; fish survival and growth would be impaired by low levels of dissolved oxygen or by the presence of toxins in the incoming water. The presence of potentially hazardous or undesirable contaminants can render water unsuitable for livestock watering or crop irrigation.

Aesthetic considerations

3.17 Pollution may affect the amenity value of freshwaters. Chapter 2 describes the progressive sequence of changes undergone by a waterbody as it becomes enriched in nutrients. In general, oligotrophic waters are clear and support a rich macrophyte flora. However, acidified lakes and rivers may often contain water which is clear but devoid of life. In contrast, severely polluted waters, such as hypertrophic lakes, or rivers contaminated with sewage, can be unpleasant to look at, foul smelling and devoid of aquatic plants and associated animals.
CHAPTER 4

HOW WATER QUALITY IS ASSESSED

Introduction

4.1 In this chapter we consider how water quality is assessed at present and draw attention to some weaknesses. We recommend a new approach to water classification, recognising that different schemes are needed for different purposes. We also conclude that the setting of statutory water quality objectives should be accompanied by action plans showing appropriate targets, timescales and means of achieving them.

4.2 At the outset we need to dispose of two related sources of potential confusion. The first is the term 'water quality' itself. This is widely used as if a single concept of water quality were immediately and universally recognisable. In fact, whether water is of high or low quality depends on the criteria against which it is judged. Traditionally these criteria have been use-related (that is, related to purposes such as abstraction for public supply or the support of fisheries). There is now interest in setting wider criteria, for instance, to assess how well waterbodies are able to support appropriate ecosystems. In each case the quality of water must be judged against criteria which relate to the role of the water. The term does not have an invariable meaning. Water might be of acceptable quality for one role but not for another.

4.3 The second clarification concerns the use of the word 'water'. The properties of pure water as a chemical compound are clearly defined. For this report, interest will more usually be in water as it occurs in the environment and importance will be attached to such matters as its temperature and the substances present in it. In judging fitness for use in public supply, information about these determinands and the presence of micro-organisms may be exactly what is needed. In other cases the quality of a waterbody as a whole is of interest. To assess this, the quality of the water itself is one of a number of features which must be described. Others might include the physical characteristics of the waterbody, the flora and fauna it supports, and variations in volume and flow. In this light, the absence of appropriate flora and fauna, perhaps because of unsympathetic dredging, may prevent a waterbody from being considered of high quality for amenity purposes.

Approaches to assessment

4.4 Freshwaters are monitored for many purposes. The setting and enforcement of discharge consents, consideration of abstraction licence applications, the suitability of water for abstraction, the checking of compliance with relevant standards laid down by law (for example to protect fisheries), and the preparation of regional or national reports on the state of the nation's waters (such as the quinquennial river quality surveys) all require extensive monitoring programmes. For water management, individual determinands (that is, specific, measurable properties) will usually need to be monitored, but in some circumstances data on a variety of determinands may be combined in an index. Although water quality indices can be helpful, within the limits of statistical significance, in presenting trends over time or in distinguishing between waters of similar but not identical quality, their value is a matter of debate. This is partly because the weighting to be given to each determinand contributing towards the index is subjective. More significantly, the combination of several determinands into a single figure may conceal changes in individual determinands.

4.5 There are two broad approaches to water monitoring. One involves examining physical and chemical characteristics of water samples, particularly to identify the presence of pollutants. The other, biological monitoring, involves examining the flora or fauna of waterbodies. Current thinking recognises that the two approaches provide complementary information and one will often compensate for deficiencies in the other.
Chapter 4

4.6 Chemical monitoring (supplemented as necessary by the monitoring of physical and microbiological determinands) has the potential to identify the substances causing pollution and to measure their concentrations at the time and location of sampling. It is essential for assessing the fitness of waters for uses which require defined physical and chemical standards. It provides the data necessary to set discharge consents and monitor effluents. Chemical measurements can be made frequently and can quickly detect very small changes from sample to sample. River quality models can be used to derive chemical standards for effluents relatively easily from the chemical composition of the receiving water. An extremely large number of chemical, physical and microbiological determinands can be monitored for one purpose or another. The DOE's Harmonised Monitoring Scheme (HMS) (see box 4.5 and paragraph 4.32) includes over 100. Those in most common use as measures of organic pollution from sewage are suspended solids (SS), biochemical oxygen demand (BOD), dissolved oxygen (DO) and ammonia. Other determinands include plant nutrients (for example phosphate and nitrate), metals (such as cadmium), micro-organic pollutants (for example pesticides) and indicator bacteria such as E.coli. Table 4.1 shows data at two sites drawn from the harmonised monitoring scheme.

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Values of some common determinands in two rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>11.6°C</td>
</tr>
<tr>
<td>pH</td>
<td>7.7</td>
</tr>
<tr>
<td>Conductivity</td>
<td>280 µS/cm</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>11.1 mg/l</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>9.59 mg/l</td>
</tr>
<tr>
<td>BOD (ATU)</td>
<td>1.6 mg/l O</td>
</tr>
<tr>
<td>Ammoniacal nitrogen*</td>
<td>0.075 mg/l N</td>
</tr>
<tr>
<td>Nitrite*</td>
<td>0.04 mg/l N</td>
</tr>
<tr>
<td>Nitrate*</td>
<td>1.34 mg/l N</td>
</tr>
<tr>
<td>Chloride</td>
<td>34.5 mg/l Cl</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>0.287 mg/l P</td>
</tr>
</tbody>
</table>

*values expressed as milligrams of nitrogen per litre. (Source: Supplement to Environmental Protection and Water Statistics No 13 1990, published 1991.)

4.7 Chemical sampling reveals information about the concentration of polluting chemicals present when the samples are taken. Nevertheless, chemical concentrations in a riverine environment fluctuate considerably in response to daily as well as seasonal variations in flow and to episodic, intermittent releases into the water. To obtain a picture which is valid for a longer period, sampling programmes can be devised to give a statistically high probability of identifying and quantifying the substances being sought and to express the results of the monitoring to a desired degree of accuracy. Some determinands are easy to monitor continuously. Although means of monitoring others continuously might be developed, it would not necessarily be either cost effective or simple to do so. In practice the number of determinands regularly sampled and the frequency of sampling is of necessity limited, with the result that some significant types of pollution may not be revealed and episodic events resulting from accidental or surreptitious discharges may have only a low probability of being detected.

4.8 The degree of pollution of a waterbody can also be estimated by monitoring indicator organisms, which respond to changes in specific contaminants or in more general environmental conditions (see box 4.1 and plate 8). Biological monitoring can indicate the cumulative effect of pollution on the ecosystem, from, for example, episodic events, unsuspected pollutants or ones
present at very low levels. Over time, the data reflect the responses of living organisms to the combination of environmental factors that lead them to flourish or decline, including changes in flow and habitat diversity which are not always reflected in water chemistry. The monitoring of biota is an especially appropriate means of judging the ecological state of a waterbody. It may in addition provide a useful measure of the level of the amenity value of waterbodies since it takes into account some of the very factors which enhance public enjoyment of them.

**BOX 4.1 BIOLOGICAL MONITORING AND BIOTIC INDICES**

<table>
<thead>
<tr>
<th>In 1908 and 1909, Kolkwitz and Marsson published fundamental work on the relationship between the biological evaluation of a stream and organic pollution. Other subsequent studies have explored the advantages of biological indicators, most commonly focusing on macro-invertebrates.</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the UK, the Trent Biotic Index, developed in the 1950s and early 1960s, was used by the former Trent River Board to indicate the presence of pollutants and classify waters. Subsequently a Biological Monitoring Working Party (BMWP), established in 1976 under the auspices of DOE and the NWC, developed a scoring system based on families of macro-invertebrates (including insects, molluscs, crustaceans, roundworms and flatworms) found in water of differing qualities, rather than individual species.</td>
</tr>
<tr>
<td>In the BMWP scheme, families such as may-flies, generally found in unpolluted, well aerated, fast flowing streams, score the maximum ten points, whilst worms and air breathing forms such as railed maggots, typical of water with high organic loadings and low oxygen levels, score one. The BMWP score is the total of the appropriate scores for the groups present, regardless of their abundance in the sample. An average score per taxon (ASPT) can also be calculated.</td>
</tr>
<tr>
<td>On the basis of their hydrology, geology and chemistry, eight different groups of aquatic sites were identified across the UK for each of which there was a typical BMWP score and ASPT. High scores were obviously associated with good quality waterbodies, whilst low scores often, but not invariably, indicated polluted waterbodies.</td>
</tr>
</tbody>
</table>

4.9 Where sampling is intermittent, an apparent discrepancy between the biological state of a waterbody and its chemical state may be attributable to several possible causes. These include unidentified or transient pollutants, and cumulative effects of low concentrations. Alternatively such a discrepancy may suggest an inadequate biological monitoring programme which is failing to assess accurately the effects of identified pollutants. Although biological monitoring of waterbodies does not identify individual pollutants or their sources, more specific diagnostic methods could be developed on the basis of the growing body of ecotoxicological data. When the results of biological monitoring suggest that pollution is occurring, other techniques may be needed to establish the cause. Biological methods of assessment may be more labour intensive, can prove more expensive (though chemical analysis is not cheap), and are not well suited to detect small changes in pollutant levels over a short period of time.

4.10 Both chemical and biological sampling programmes may be constrained by cost and practicality. Samples may be taken too infrequently or at unrepresentative times and places. The results are not always analysed to a consistently high standard. These factors can lead to waters being wrongly classified, false trends implied or real trends overlooked. It is therefore of the highest importance that the objectives of monitoring schemes are clearly defined from the outset and the programmes devised to achieve an acceptable degree of statistical reliability (see paragraph 4.35).
Chapter 4

General classification schemes

4.11 The chief purpose of general classification schemes is to present a broad picture of the state of rivers and other waters. Such pictures can be used to identify major priorities for investment and for pollution control on a national scale. They also offer a rough indication of achievement in protecting and improving the water environment, and thus of the performance of the responsible authorities. For some years, river quality surveys have been carried out in the UK in order to fulfil these needs and to allow an assessment of how effectively the policy of successive governments, to maintain and improve water quality, has been implemented. In theory, a sequence of surveys should allow trends to be identified. In practice, interpretation of survey results and comparison between surveys can be problematical. In the past, general classification schemes have been used for water quality planning and management purposes. The NWC scheme has been widely used to establish local water quality targets and to set discharge consents.

Current methods of river classification

4.12 Since 1980 surveys in England, Wales and Northern Ireland have provided information for a classification scheme devised by the former National Water Council (NWC) and based mainly on physical and chemical determinands (see table 4.2). In this report we refer to it as the NWC scheme. The intention was ‘to provide a common basis for both a general description of use and a scientific description of the corresponding limits on quality’. It defined four classes of water, the first of which was subdivided, with descriptions ranging from suitability for potable abstractions, game or other high class fisheries, and high amenity value (class 1A), to grossly polluted and likely to cause nuisance (class 4). Determinands including DO, BOD, ammonia and fish toxicity were used in order to define quantitatively the boundaries between the classes. Some of the requirements of the EC surface water directive (75/440/EEC) were added to the quality criteria for stretches of river where water was abstracted for potable supplies.

4.13 The NWC scheme was set up partly in terms of fishery uses and partly in terms of the treatment that would be required before a water would be suitable for potable supply. The scheme was judged inappropriate for Scotland, largely because fewer rivers are used for potable supply. Water quality surveys there have been carried out with the aid of a classification scheme which contains four classes with less detailed descriptions but with similar, if more subjectively assessed, determinands (see table 4.3).

Validity of current methods of classification

4.14 The NWC scheme has some features which reduce its value both as a management tool and as a general indicator of the state of waterbodies. First, it purports to incorporate both the EC surface water directive and the European Inland Fisheries Advisory Commission (EIFAC) criteria. This inevitably makes it impossible to see a clear picture of the state of the water, since the same determinands have different limits under these instruments. The same stretch of water could be classified either as class 1A or class 3 under the NWC scheme depending on whether its ammonia concentration was judged against the EIFAC requirements or the surface water directive.

4.15 Moreover, the ranking of classes ranging from 1A to 4 can produce misunderstandings if the scheme is then interpreted as a guide to the degree of pollution in rivers. It is clear that not all rivers classified as 1B in the NWC scheme are in that class on account of pollution. Either permanently or intermittently, some unpolluted waters, particularly lowland waters, may naturally have too low a concentration of dissolved oxygen or too high a BOD ever to become 1A.

4.16 In order to provide continuity, the river quality survey carried out in England and Wales in 1990 replicated so far as possible the procedures used in 1985. However, because of the defects in the NWC classification scheme, the former Water Authorities Association had recommended a new classification system based solely on BOD, DO and ammonia and the NRA has proposed that this should be used in future to define NRA chemical classes. The criteria for these NRA classes are shown in table 4.4. In all significant respects they are the same as the criteria for these determinands in the NWC scheme. Nevertheless, when the results of the 1990 survey are assessed
### Table 4.2
NWC river quality classification scheme

<table>
<thead>
<tr>
<th>River Class</th>
<th>Quality criteria</th>
<th>Remarks</th>
<th>Current potential uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1A Good Quality</strong></td>
<td>Class limiting criteria (95 percentile)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>Dissolved oxygen saturation greater than 80%</td>
<td>(i) Average BOD probably not greater than 1.5 mg/l</td>
<td>(i) Water of high quality suitable for potable supply abstractions and for all other abstractions</td>
</tr>
<tr>
<td>(ii)</td>
<td>Biochemical oxygen demand not greater than 3 mg/l</td>
<td>(ii) Visible evidence of pollution should be absent</td>
<td>(ii) Game or other high class fisheries</td>
</tr>
<tr>
<td>(iii)</td>
<td>Ammonia not greater than 0.4 mg/l</td>
<td></td>
<td>(iii) High amenity value</td>
</tr>
<tr>
<td>(iv)</td>
<td>Where the water is abstracted for drinking water, it complies with requirements for A2* water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(v)</td>
<td>Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **1B Good Quality** | (i) DO greater than 60% saturation | (i) Average BOD probably not greater than 2 mg/l | Water of less high quality than Class 1A but usable for substantially the same purposes |
| (ii) | BOD not greater than 5 mg/l | (ii) Average ammonia probably not greater than 0.5 mg/l | |
| (iii) | Ammonia not greater than 0.9 mg/l | (iii) Visible evidence of pollution should be absent | |
| (iv) | Where water is abstracted for drinking water, it complies with the requirements for A2* water | (iv) Waters of high quality which cannot be placed in Class 1A because of the high proportion of high quality effluent present or because of the effect of physical factors such as canalsiation, low gradient or eutrophication | |
| (v) | Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available) | (v) Class 1A and Class 1B together are essentially the Class 1 of the River Pollution Survey (RPS) | |

| **2 Fair Quality** | (i) DO greater than 40% saturation | (i) Average BOD probably not greater than 5 mg/l | Waters suitable for potable supply after advanced treatment |
| (ii) | BOD not greater than 9 mg/l | (ii) Similar to Class 2 of RPS | (ii) Supporting reasonably good coarse fisheries |
| (iii) | Where water is abstracted for drinking water, it complies with the requirements for A3* water | (iii) Water not showing physical signs of pollution other than humic colouration and a little foaming below weirs | (iii) Moderate amenity value |
| (iv) | Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available) | | |

| **3 Poor Quality** | (i) DO greater than 10% saturation | Similar to Class 3 of RPS | Waters which are polluted to an extent that fish are absent or only sporadically present. May be used for low grade industrial abstraction purposes. Considerable potential for further use if cleaned up |
| (ii) | Not likely to be anaerobic | | |
| (iii) | BOD not greater than 17 mg/l | | |
| This may not apply if there is a high degree of re-aeration | | |

| **4 Bad Quality** | Waters which are inferior to Class 3 in terms of dissolved oxygen and likely to be anaerobic at times | Similar to Class 4 of RPS | Waters which are grossly polluted and are likely to cause nuisance |

| **X** | DO greater than 10% saturation | | Insigificant watercourses and ditches not usable, where the objective is simply to prevent nuisance developing |

**Notes**

(a) Under extreme weather conditions (eg flood, drought, freeze-up), or when dominated by plant growth, or by aquatic plant decay, rivers usually in Class 1, 2 and 3 may have BODs and dissolved oxygen levels, or ammonia content outside the stated levels for those Classes. When this occurs the cause should be stated along with analytical results.

(b) The BOD determinations refer to 5 day carbonaceous BOD (ATU). Ammonia figures are expressed as NH₃.

(c) In most instances the chemical classification given above will be suitable. However, the basis of the classification is restricted to a finite number of chemical determinands and there may be a few cases where the presence of a chemical substance other than those used in the classification markedly reduces the quality of the water. In such cases, the quality classification of the water should be down-graded on the basis of biota actually present, and the reasons stated.

(d) EIFAC (European Inland Fisheries Advisory Commission) limits should be expressed as 95 percentile limits. * EEC category A2 and A3 requirements are those specified in the EEC Council Directive of 16 June 1975 concerning the Quality of Surface Water Intended for Abstraction of Drinking Water in the Member State.
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Table 4.3  
Scottish river quality classification scheme

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Rivers Unpolluted or Recovered from Pollution</td>
</tr>
<tr>
<td></td>
<td>Lengths of river:</td>
</tr>
<tr>
<td></td>
<td>(a) where the water is clear and which are known to have received no significant polluting discharges; or</td>
</tr>
<tr>
<td></td>
<td>(b) which, though receiving some pollution, have a BOD normally less than 3 mg/l, are well oxygenated and are known to have received no significant discharges of toxic materials or of suspended matter which affects the river bed.</td>
</tr>
<tr>
<td>Class 2</td>
<td>Rivers of Fairly Good Quality</td>
</tr>
<tr>
<td></td>
<td>Lengths of river:</td>
</tr>
<tr>
<td></td>
<td>(a) not in Class 1 on BOD grounds; or</td>
</tr>
<tr>
<td></td>
<td>(b) which may have a substantially reduced oxygen content; or</td>
</tr>
<tr>
<td></td>
<td>(c) irrespective of BOD, which are known to have received polluting discharges, possibly containing toxic substances, which cannot be shown either to affect fish or to have been removed by natural processes.</td>
</tr>
<tr>
<td>Class 3</td>
<td>Rivers of Poor Quality</td>
</tr>
<tr>
<td></td>
<td>Lengths of river:</td>
</tr>
<tr>
<td></td>
<td>(a) not in Class 4 on BOD grounds; or</td>
</tr>
<tr>
<td></td>
<td>(b) which may have a dissolved oxygen saturation below 50% for considerable periods; or</td>
</tr>
<tr>
<td></td>
<td>(c) containing substances which are suspected of reaching toxic concentrations at times.</td>
</tr>
<tr>
<td>Class 4</td>
<td>Grossly Polluted Rivers</td>
</tr>
<tr>
<td></td>
<td>Lengths of river:</td>
</tr>
<tr>
<td></td>
<td>(a) which have an offensive appearance or smell; or</td>
</tr>
<tr>
<td></td>
<td>(b) which have a BOD of 12 mg/l or more under normal conditions; or</td>
</tr>
<tr>
<td></td>
<td>(c) which are completely de-oxygenated at any time; or</td>
</tr>
<tr>
<td></td>
<td>(d) which contain substances known to reach toxic concentrations at times; or</td>
</tr>
<tr>
<td></td>
<td>(e) which are known to be incapable of supporting fish life.</td>
</tr>
</tbody>
</table>

using these criteria, there is a very marked reduction in the length of class 1A rivers (a reduction from 31% to 12%) and substantial increases in class 2 and 3 rivers. The comparative results are shown in table 4.5. The NRA ascribes the differences mainly to a more rigid application of the classification rules than was common under the NWC scheme. In particular, unlike the NWC scheme, subjective judgment was not allowed to over-ride suspected errors in the data or in the resulting NRA classification, where the authorities felt the results misrepresented the quality of the river. Indeed it appears that the element of subjective judgment in the application of the NWC scheme was considerable. Moreover, the NRA states that the lack of consistency in the way this judgment was applied, both across the country and from one survey to the next, made comparison of the results problematic. Thus, although the scheme appears to be objective, it transpires that the published results do not bear a consistent relationship to the underlying chemical monitoring, because of differences in the mathematical procedures used and the inclusion of subjective assessments.
Table 4.4
Chemical criteria for the NRA classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Dissolved Oxygen (5-percentile % saturation)</th>
<th>Biochemical Oxygen Demand (ATU) 95-percentile (mg/l)</th>
<th>Ammonia (mgN/l) 95-percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>80</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>5</td>
<td>0.7</td>
</tr>
<tr>
<td>C</td>
<td>40</td>
<td>9</td>
<td>3.0</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>17</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>&lt;10</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Note: The 5-percentile dissolved oxygen standards require that the percentage saturation exceeds the values shown in the table, whereas the 95-percentile standards require that the values are not exceeded. The use of percentile standards is explained in appendix 6.

Source: NRA, Water Quality Series No 5.

Table 4.5
Comparison of the preliminary results of the 1990 survey, using the NWC classification scheme and the NRA (chemical data only) scheme

<table>
<thead>
<tr>
<th>NWC Class</th>
<th>% Length in Class</th>
<th>NRA Class</th>
<th>% Length in Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>31</td>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>1B</td>
<td>34</td>
<td>B</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>C</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>D</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>E</td>
<td>3</td>
</tr>
</tbody>
</table>

These results are from a preliminary assessment of the 1990 Survey. Full results, including chemical and biological data, are due to be published during 1992.

Source: NRA, Water Quality Series No 5.

4.17 There is also disparity between the number of determinands apparently covered by the NWC scheme and the small number (usually DO, BOD, SS and sometimes ammonia) which are regularly monitored. For some purposes, those few alone may be sufficient but they do not give a comprehensive picture of the state of UK rivers. Many water uses are profoundly influenced by the presence of other substances including plant nutrients, pesticides and metal salts. These are especially likely to affect the nature of a waterbody as a wildlife habitat. It is unrealistic, however, to expect a general classification scheme based on physical and chemical determinands to take account of an ever-expanding range of chemicals and water uses and remain practicable.

Use-related classification schemes

4.18 Although general classification schemes give a broad indication of freshwater pollution, it may be necessary to assess more exactly the fitness of waters for specific purposes, such as water
**Chapter 4**

**BOX 4.2 BIOTIC INDICES — GERMAN SAPROBIC INDEX**

The saprobic character of water is indicated by its content of putrescible material and is reflected in the species composition of its biological community. Aquatic organisms flourish or decline according to the level of organic pollution. Catalogues have been prepared which characterise thousands of species, including all types of organisms found in freshwater, by their association with particular saprobic zones. Four biologically characterised zones can be distinguished:

IV *Polysaprobic zone* which has very heavy organic pollution; micro-organisms predominate; species diversity is low but density is often high; macro-organisms and other species with high oxygen demands are absent; decomposers are dominant while plants are almost completely absent.

III *Alpha-mesosaprobic zone* which has heavy organic pollution; numerous species of micro-organisms; a few macro-organisms (i.e. fish and plants) are encountered.

II *Beta-mesosaprobic zone* which has a moderate organic load; this zone has optimum living conditions for many organisms.

I *Oligosaprobic zone* which has high water quality and almost complete absence of organic load; macro-organisms predominate; species diversity is high but density is usually low.

Determining the saprobic index requires a biological survey of the sampling point. The indicator species found are scored for their abundance on a seven point scale of relative frequency. The saprobic index is calculated from a formula that includes the frequencies of occurrence of organisms associated with each of the four saprobic zones. The resulting saprobic index ranges from 1.0 to 4.0 with higher values registered by more polluted waters.

A classification scheme has been devised comprising the four zones and three intermediate categories identified as I/II, II/III, and III/IV.

Biological assessment and classification

4.19 The degree of organic pollution found in water determines to some extent the nature of the aquatic biota supported. This relationship is the basis of the German saprobic index (see box 4.2), which uses a formula to convert the results of a biological survey at the sampling point to a score on an index. A classification scheme is produced by dividing the index into seven classes which broadly correspond to the four saprobic stages described in the box together with three intermediate stages. Physical and chemical measurements are also taken and related broadly to the classes.

4.20 Biological communities are sensitive not only to pollution and other man-made interference but also to natural phenomena. The River Invertebrate Prediction and Classification System (RIVPACS) has been devised *inter alia* to enable the effects of pollution to be isolated from basic physical and chemical influences in the biological assessment of waterbody quality (see box 4.3). RIVPACS predicts the probability of capture of each BMWP family, from which it calculates the Biological Monitoring Working Party (BMWP) score, the average score per taxon (ASPT) and the taxa numbers which would be obtained at a given site if it were unpolluted. Comparison with what is actually found gives an indication of the biological state of the river.
BOX 4.3 BIOTIC INDICES — RIVPACS

Biological indices seek to measure the degree of pollution of a waterbody by assigning scores to the presence of specific flora or fauna. Generally organisms which are intolerant of pollution are given a high score so that waters associated with an overall high score can be considered to be unpolluted. Macro-invertebrates have often been preferred as the indicator organisms as they are present in all waterbodies, except the most polluted. They represent several trophic levels and feeding types, and are easy to sample. Larger water plants tend to be more tolerant of pollution and lack the sensitive responses of invertebrates, algae are not so easy to sample and identify, while fish are mobile and tend to avoid polluted water.

A major criticism of biological indices is that they are best fitted to the waterbodies on which they are initially developed and application to other areas where different conditions and habitats occur is liable to lead to misleading assessments.

The River InVertebrate Prediction And Classification System (RIVPACS) has been developed by the Institute of Freshwater Ecology in collaboration with the water industry to overcome this objection. RIVPACS differs from the BMWP scoring system by comparing the scores of the macro-invertebrate communities found at a given site with the community scores that would be predicted to occur under optimum conditions. In order to establish the community that the site should support some 438 apparently unpolluted sites on 80 rivers in Great Britain were surveyed. The baseline sites were chosen as the best examples of each type of waterbody available. Sites grouped by their animal communities were found to share similar physical and chemical features, such as width and depth of waterbody, substratum type, distance downstream, slope, altitude and total alkalinity. The chemical indices chosen are, as far as possible, independent of organic pollution. On the basis of these site features, the RIVPACS software predicts the fauna at other sites. The prediction can be compared with the fauna that is observed and a score can be assigned on an Ecological Quality Index (by dividing the observed score by the predicted score). Discrepancies between the predicted and the observed fauna may be the result of environmental stress such as habitat loss, and be apparent as the absence of a sensitive family or abundance of a tolerant one.

The RIVPACS approach generates several indices of environmental quality; although related, each provides a different perspective on the information collected. The final results of the survey are scored on a scale divided into four biological classes (A to D) which combine the different approaches.

This is usually expressed as an index calculated by dividing the observed biological state, expressed as BMWP score, ASPT or taxa numbers, by the predicted state. The lower the index, the more the site is suffering from pollution or other detrimental factors.

4.21 The average score per taxon and Biological Monitoring Working Party score differ in their sensitivity to seasonal variation, increase in sampling effort and the sampling site, both across the river, and along it from source to mouth. ASPT is generally less sensitive than the BMWP score to seasonal variations whereas BMWP scores in spring and autumn differ significantly from summer ones at the same site. BMWP scores increase substantially with increased sampling effort. ASPT is much less sensitive in this respect. Both scores are higher when river margins are sampled rather than the centre but the ASPT is less markedly so. ASPT decreases relatively steadily from the source of a river to its mouth. BMWP scores increase in the middle reaches because there nutrient levels are sufficiently high and turbidity low enough to promote diverse communities. ASPT thus differentiates between sites which have similar BMWP scores but different physical and chemical characteristics. These factors make ASPT easier and more reliable to use as a predictive tool and we therefore favour its use in preference to BMWP.

4.22 It must be noted that RIVPACS is still under development. It is possible that the apparently unpolluted sites on which predictions are based may be more polluted than was believed. Although it is normal practice, kick sampling is in some respects crude and the choice of
sites may be open to subjectivity. RIVPACS gives confidence limits for its predictions, but they do not embrace all the uncertainties affecting the predictions. The relationships between the physical and geographical characteristics of the rivers sampled and the species found may need further investigation and refinement before RIVPACS can be fully relied on as a classification tool. At present it covers only invertebrate species in a river. Other species, including aquatic flora, may respond differently to pollution; there is scope for gradually expanding the range of species on which predictions are based so as to be able to identify pollutants which do not manifest themselves in the invertebrate populations but may have subtle effects on other species such as fish.

4.23 Deficiencies such as these are to be expected when a new methodology comes into use. The potential advantages of RIVPACS are such, however, that it justifies the time and effort needed to refine it. Subjectivity in the choice of sampling sites could be controlled by protocols. The range of biota examined could be extended even at the cost of greater difficulty of identification. An improved data-base could improve confidence in the predictions.

**Table 4.6 Biological classification of rivers**

<table>
<thead>
<tr>
<th>EQI (ASPT)</th>
<th>EQI (Taxa nos)</th>
<th>EQI (BMWP)</th>
<th>Biological Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.89</td>
<td>0.79</td>
<td>≥0.75</td>
<td>A</td>
<td>Good</td>
</tr>
<tr>
<td>0.77–0.88</td>
<td>0.58–0.78</td>
<td>0.50–0.74</td>
<td>B</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.66–0.76</td>
<td>0.37–0.57</td>
<td>0.25–0.49</td>
<td>C</td>
<td>Poor</td>
</tr>
<tr>
<td>&lt;0.66</td>
<td>&lt;0.37</td>
<td>&lt;0.25</td>
<td>D</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

Source: Scottish Office Environment Department

**Water quality classification for the future**

4.24 In parallel with the traditional surveys, RIVPACS was used to assess the biological state of surface waters for the 1990 river quality surveys throughout the UK (1991 in Northern Ireland). The full results have not yet been published. From experience of operating the NWC scheme as well as of the 1990 river quality survey, the NRA has suggested that, if a general classification scheme is needed, a replacement for the NWC scheme should be developed to minimise subjectivity, secure consistency and control the risk of mis-classification. It argues that both chemical and biological information are important for water quality management and that their combined use could reduce the risk of misclassifying rivers. It has illustrated this argument by a scheme with strictly applied chemical criteria and, in addition, a 'biological over-ride' to be used with the chemical data to assign quality classes (see box 4.4). In order to reduce the risk of overestimating changes in class in the future surveys, it has also proposed that each survey should use 3 years’ data, thus increasing the scope of the sample on which the results are based, and that rivers should not be assigned to a different class from the previous survey unless the monitoring data show a statistically significant difference.

4.25 We agree that the full range of biological and physical/chemical monitoring must be available to guide the management of freshwater resources. We do not, however, see this as a convincing argument for combining them in a general classification scheme. To do so would obscure the issues by trying to combine assessments of the causes of biological deterioration and their effects. Moreover general classification schemes are not well suited for routine water quality management purposes which are better met by development of the system of water quality objectives described at paragraph 4.42 et seq.

4.26 The prime purpose of a general classification scheme should be to provide a general picture of the biological state of the aquatic environment. The most meaningful way to do this is to move as closely as possible to monitoring the aquatic biota and the Scottish Office has already
In its consultation paper on the implementation of statutory water quality objectives, the NRA has suggested that there may be value in developing a new general classification scheme in order to make general statements about the states of similar types of water at any one time.

One approach might be to combine biological information with chemical data to provide a more integral assessment of water quality than in the NWC scheme and improve precision in placing a stretch of river in a class during river quality surveys.

As an illustration, the NRA has devised a classification scheme with five classes defined by reference to chemical criteria similar to those in the NWC scheme for DO, BOD and ammonia (see table 4.2). Strict, uniform rules could be applied to sampling procedures and the analysis of results to ensure consistency of approach. The worst of the three determinands could determine the initial allocation of a stretch of river to a class.

Biological information could then be used in order to correct initial class allocations based on chemical criteria, which are considered to misrepresent the biological state of the river.

The methodology is still under development but for illustrative purposes, the NRA has used for this purpose an Ecological Quality Index (EQI) based on the ratio of observed to predicted Average Score Per Taxon. Index ranges could be set for each of the five classes, for example:

<table>
<thead>
<tr>
<th>NRA Class</th>
<th>Ecological Quality Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.90 to 1.00</td>
</tr>
<tr>
<td>B</td>
<td>0.65 to 0.99</td>
</tr>
<tr>
<td>C</td>
<td>0.60 to 0.85</td>
</tr>
<tr>
<td>D</td>
<td>0.40 to 0.65</td>
</tr>
<tr>
<td>E</td>
<td>Zero to 0.55</td>
</tr>
</tbody>
</table>

The EQI bands could be used to assess whether a change in class was justified. A river whose chemistry placed it in class C would be downgraded if its EQI score were less than 0.60 and upgraded if its score were more than 0.85.

The above example illustrates how a general classification scheme could be used to produce a similar national picture to the NWC scheme without the use of subjective judgment. Further analysis of the results of the 1990 survey may lead to the development of different proposals.

4.27 We also recommend that the regulatory authorities should move towards a system of reporting results by volume as well as by length of rivers. As the Royal Commission pointed out in its Fourth Report, surveys based solely on length can allow the many miles of small, fast-flowing and relatively unpolluted rivers to give a misleading impression of the available quantity of clean, compared with polluted, water. Information on river flow rates is already available to the regulatory authorities and it would not be difficult to present the quality results by averaged volume as well as length.
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Physical, chemical and microbiological monitoring

4.28 Physical, chemical and microbiological determinands must continue to be monitored in order both to explain changes in the biological indices and to meet the particular needs of water quality managers, (for example in setting and monitoring discharge consents). For water quality management, monitoring systems must be tailored to the precise purpose they are intended to serve. To explain changes in the biological state of a river, we recommend that a larger number of determinands should be monitored than the three main ones in the NWC and NRA classification schemes. They should be chosen to reflect all types of water pollution and should include data on nitrate and phosphate, on microbiological indicators, and on the presence of heavy metals and key pollutants such as pesticides. Presentation of the levels of, and trends in, the separate determinands would be valuable and of considerable public interest.

4.29 Our recommendations would result in periodic biological assessments of UK rivers whose results would be published quinquennially. There would also be a separate process of collecting chemical data which could be published more frequently, perhaps annually. The two sets of information would undoubtedly reveal discrepancies in the way they described particular rivers and perhaps in the overall view they gave of UK rivers. We do not see this as a disadvantage since these discrepancies may shed new light on some pollution problems, lead to the further improvement of the monitoring and predictive systems, and, at the very least, demonstrate that there is no single quality standard for water. Indeed there may be some interest in devising additional means of presenting the biological and chemical quality assessments together so as to illustrate the extent of agreement or disagreement between the results of the two procedures.

4.30 Much of the monitoring that would be needed to present a national picture of levels and trends for important determinands already takes place. During the course of this study we have been impressed by the substantial amount of monitoring of rivers that takes place in the UK. The NRA spends some £10 million pa on monitoring (including its work on estuaries and coastal waters), and has 11 main laboratories and over 450 staff devoted to monitoring effluents and water quality. Substantial resources are also devoted to these tasks by water companies, the river purification authorities in Scotland and by DOE(NI). Since July 1985 there has been a requirement for information about water and effluent samples taken for monitoring purposes to be available for public inspection in registers held locally by the authorities. This needs to be supplemented by co-ordinating the results across the country, for an agreed range of determinands, and reporting them in a digested form for public information.

4.31 At present, there are some aspects of freshwater quality for which no complete national picture is published. The Government publishes some information annually in the Digest of Environmental Protection and Water Statistics, partly reporting data collected in accordance with EC directives. Similarly, the Drinking Water Inspectorate reports on compliance with the drinking water directive. The NRA has published a comprehensive survey of compliance with the bathing waters directive and has stated its intention of publishing reports on other directives under which it has specific duties. Friends of the Earth last year produced an analysis of compliance with the freshwater fish and dangerous substances directives which achieved prominent press coverage. Data on these directives had been reported to the EC Commission by the Government but had not previously been collated and interpreted to the public in such a form. It should not be necessary to wait for the stimulus of EC directives and other international obligations before collecting, analysing and publishing information in a readily digestible form. The Government stated in its White Paper This Common Inheritance that 'environmental statistics need to be brought together in a more coherent and comprehensive form to provide the necessary benchmark against which progress can be assessed.' The water environment is an area where there is considerable scope for this.

Harmonised monitoring scheme

4.32 The basis of a fuller presentation of water data has in fact existed for nearly 20 years in the Harmonised Monitoring Scheme (HMS), currently operated by HMIP. This scheme is described
in detail in box 4.5. It covers over 200 sites in the UK and more than 100 determinands, about 25 of which are sampled regularly. Little comprehensive information from the scheme, however, has ever been published.

4.33 This is a lost opportunity. A lot of time, effort and money were clearly expended in establishing the scheme, authorities throughout the UK are still utilising resources for it in sampling and analysing water and HMIP is maintaining a computerised data-base and analytical capability. The scheme has considerable potential for providing, on a consistent and comparable basis, a national picture of a range of important determinands and an indication of long term trends in these determinands. Such a picture would be of considerable public interest, consistent with the original purpose of the scheme and in line with the Government's aim in its White Paper. In chapter 6 we have used data from the scheme to give a broad picture of phosphate levels in rivers in England and Wales. Similar analyses could be carried out for other substances.

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**BOX 4.5 HARMONISED MONITORING SCHEME**

In 1974 the Department of the Environment established with the then Water Authorities in England and Wales a scheme to monitor river water quality on a harmonised basis. A parallel Scottish scheme was initiated by the then Scottish Development Department (now SOEnD). Over 200 sites were selected (see figure 4.1) and one site in Northern Ireland was subsequently added. This harmonised monitoring scheme originally covered nearly 80 determinands and was subsequently expanded to include over 100. The scheme's purposes were:

1. To enable an estimate to be made, in connection with the United Kingdom's international obligations, of materials carried down rivers into estuaries.
2. To enable long-term trends in river water quality to be identified.

The intention was to publish annual summaries of the data.

Considerable efforts were made by the DOE and the water industry in the early years of the scheme to collect data using harmonised methods of sampling and analysis, to establish a system of analytical quality control and to determine appropriate sampling frequencies so that statistical confidence limits could be put on the accuracy of the results. The sampling points, which covered all significant rivers, were generally located at or near the tidal limits and on major tributaries. Some additional points were included along major rivers. The sites are thus neither random nor comprehensive. They are, however, representative of the major rivers and especially of their lower reaches.

Responsibility for maintaining the records of samples under the scheme currently resides with HMIP which receives data from the NRA, SOEnD and RPAs. A computerised system contains information about all the samples taken since the scheme started. The central co-ordination of data collection and the efforts to ensure consistency across the country ceased, however, in the mid-1980s when DOE withdrew its funding for this activity. In practice, only about 25 determinands are monitored regularly and DOE is entirely dependent on the organisations providing the data for its coverage and frequency, a situation that seems to have led to some unfortunate discontinuities in reporting of determinands and coverage of sites.

DOE uses the data to assist in policy formulation and to calculate the loads of metals and other substances discharged to the seas from rivers. Samples of the data for a small number of sites have been published by the Institute of Hydrology. A slightly larger selection is published in supplements to DOE's annual Digest of Environmental Protection and Water Statistics. Some data are also published in Scottish environment statistics. Comprehensive information from the scheme is not, however, publicly available.

Figure 4.1 Harmonised monitoring sites in the United Kingdom

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4.34 If full value is to be obtained from the scheme, harmonisation of data collection and quality control must be re-established so that those providing the information and those using it have a proper understanding of each other's requirements. Publication of the information and feedback to providers of information have an important part to play in maintaining a reliable, critical and complete data-base. These are lacking at present. We recommend that the Government should convene a working party which includes representatives of the NRA and RPAs to consider the overall objectives of the scheme and to develop means of achieving these aims. This working party should also review the coverage of sites and determinands and consider the addition of biological monitoring. While the sites now in use may give good coverage for calculating pollutant loads to the sea, upland areas, for example, are not well represented (see figure 4.1). In contrast, the range of determinands may be too wide for regular monitoring and agreement should be sought on a more limited selection which would be measured frequently. The working party should consider the best way of presenting to the public the information collected through the scheme so that it offers a national picture of progress in controlling a selected range of important determinands. This might be done on an annual basis with a commentary discussing the implications of the figures.

Design of monitoring programmes

4.35 We pointed earlier in this chapter to some of the defects commonly found in both biological and chemical monitoring schemes and the presentation of their results. There is inevitably a difference between the true state of a river, which itself varies from time to time and place to place, and the state which is calculated from the results of sampling. Estimates of the state of the river from samples (which may typically be no more than 12 per annum) will carry a degree of uncertainty leading to a risk that rivers may be incorrectly classified. This risk may be high if the classes in the scheme are narrow and the sampling results carry a high degree of uncertainty. This is in fact the case with classes 1A, 1B and 2 of the NWC scheme to the extent that the NRA estimates 'a probability of 20-30% that a site may be declared to have changed class when the true quality of the site has not changed at all'. Sampling error can be estimated, but cannot be eliminated. The degree of error which is tolerable in classifying rivers must therefore be identified and a sampling programme drawn up which will enable this requirement to be met with a given level of confidence.

4.36 The analysis of samples often produces inconsistent results from sample to sample or laboratory to laboratory with potentially misleading results. Proper analytical quality control procedures should be applied in order to minimise such errors and should be supplemented by regular, inter-laboratory calibration exercises. Although these techniques are employed, there is scope for their further improvement and more widespread use. These ideas, and the similar issues that arise in sampling effluents in order to determine compliance with consents, are discussed in more detail in appendix 6.

Headwaters

4.37 The NRA has estimated that there are about 150,000 first order headwater streams (i.e. those without tributaries) in mainland Britain, representing some 75% of the length of the nation's rivers and streams. They may have local importance as wildlife habitats and for public amenity. Upland streams may be important breeding grounds for salmonids. In reviewing almost 1,000 sites the NRA has identified 101 macro-invertebrate taxa (some of which are rare or nationally threatened) specifically associated with British headwaters. The current NWC classification scheme has not normally been applied to rivers with a summer flow of less than 0.05 cubic metres per second unless they have been considered important by the regulatory authorities. The scheme allocates many headwaters to a class (class X) of watercourses and ditches which are described as 'insignificant' and 'not usable' and where the objective is 'simply to prevent nuisance developing'. Class X watercourses are usually omitted from the survey as they are 'by definition insignificant and therefore not appropriate to a national survey'. There is a dilemma here. The cost of regularly monitoring these streams would be high but, where such streams are polluted, they have a local environmental impact and they introduce pollutant loads.
to larger rivers into which they flow. In the absence of this information, the causes of poor quality in larger rivers may be misunderstood. We recommend that small watercourses should be monitored from time to time (perhaps using rapid biological screening methods) and action taken to remedy any problems revealed.

Standing waters

4.38 The NWC classification scheme is intended to take lakes into account if they form part of a river system (though it is not clear how far this has been done in practice). Other standing waters (lakes, ponds, reservoirs etc) are not included. Several EC member states, however, classify their standing waters using a scheme developed by the OECD. The scheme compares the trophic state of a lake with that of a similar but unpolluted lake in order to assess the pollution and thus classify the quality of the water. The OECD scheme consists of a set of five classes (ultra-oligotrophic, oligotrophic, mesotrophic, eutrophic, hyper-eutrophic) and takes into account the transparency of the water, the concentration of chlorophyll-a (as a measure of algal density) and total phosphorus (see chapter 6, table 6.1).

4.39 We discuss in Chapter 6 the increasing concern over the nutrient enrichment of freshwater and the obligation (in the recently agreed urban waste water treatment directive) for EC member states to identify ‘sensitive’ waters. In the context of classification schemes, we consider that there is value in standardising the approach to defining trophic states and the extent of nutrient enrichment by pollution. We recommend that UK standing waters of 0.4 hectares (about one acre) and above should be surveyed and classified on a regular basis and that as far as possible the classification should adopt an internationally recognised system such as the OECD one. Development of biological indicators using similar principles to RIVPACS would also be desirable and we recommend that the Government should encourage research for this purpose.

4.40 There is often amenity and wildlife habitat value in standing waters such as ponds which are too small to be included in the national quality surveys (ie below 0.4 hectares). However, as polluted ponds can be a serious disamenity and adversely affect wildlife, there is a case for assessing and improving them on the basis of their local nature conservation and amenity value. A National Pond Survey has been initiated by Pond Action and we welcome this attempt to increase understanding of the ecology of ponds and other freshwaters and to adopt appropriate conservation and management techniques.

Groundwater

4.41 The importance of protecting groundwater from pollution is being increasingly recognised. We have considered whether a general classification scheme for groundwater would help in monitoring trends in quality as well as preserving and, where necessary, improving it. We consider that, given the absence of comprehensive data and the difficulty of designing classes which would provide helpful assessments of the waters, no single meaningful general classification scheme could be constructed but specific schemes for particular purposes could be usefully developed. These need not be restricted (as the NRA suggests) to the determinands in the drinking water directive. The lack of significant fauna in groundwaters means, however, that biological schemes could not be used. Our recommendations for monitoring and protecting groundwater are in chapter 5.

Statutory water quality objectives

4.42 For some years, improvements in the state of waters have been planned and assessed using non-statutory river quality objectives. The Water Act 1989 first empowered the Government to set statutory water quality objectives (SWQO) which could formalise the means of achieving improvements (see box 4.6). This new power opens up challenging opportunities for the Government. There have hitherto been only general expressions of national policy on water quality. In England and Wales, the aim is to eliminate class 4 and steadily reduce class 3 rivers'. In Northern Ireland, the objective is to manage river and estuarine systems so that water quality
is at least Class 2 with no downward movement between classes. In Scotland, the independent River Purification Authorities set the non-statutory objectives for waters in their areas. We were told that they have sought to achieve the highest standards reasonably practicable in the circumstances of individual waters—the ideal being to aim for salmonid quality. Where this has been impracticable, their aim has been to achieve a steady improvement in water quality. This was confirmed by the Clyde River Purification Board which had the aim of achieving class I quality for all its waters and which demanded commensurate improvements to discharges when it sought to tighten consents. Similarly, the Forth River Purification Board aims to reduce by one third the length of poor waters within its catchment by 1995. Except in the case of the Forth RPB, timescales have not yet been expressed for the achievement of most of these aims but the Government will be obliged to address the point directly in setting the first statutory objectives.

**BOX 4.6 STATUTORY WATER QUALITY OBJECTIVES**

Following recommendations made by the former National Water Council (NWC) in 1977, non-statutory river quality objectives have been used as a basis for setting discharge consents and for planning investment to improve water quality. The objectives, which in England and Wales have usually been defined in terms of NWC classes, have been consistent with either the current use of the relevant water or a longer term target use. These objectives have been underpinned by quality standards set for chemical and other determinands which generally represent the maximum levels which could be present in the water if its current or intended future use was to be maintained. Discharge consents have then been set in the light of concentrations of pollutants already in the water with allowances made for mixing and dilution. Water quality standards to protect a particular use of water (such as fisheries) have been applied to river quality management. In the former Anglian Water Authority such standards were an integral part of the water quality management system.

The Water Act 1989 (and subsequently the Water Resources Act 1991) provided the power to develop a system of statutory water quality objectives (SWQOs) for the purpose of maintaining and improving controlled waters. The Act enables the Secretary of State to prescribe, in Regulations, a system of classifying the waters subject to the scheme. The criteria to be used can consist, either separately or in combination, of:

(a) general requirements with regard to the purposes for which the waters are to be suitable;
(b) substances which are present in, or absent from, the water, and their concentrations; or
(c) specific requirements as to any other characteristics of the water.

These classifications have effect only if incorporated into water quality objectives. A SWQO is set by the Secretary of State's serving notice on the regulatory authority specifying a stretch of water and the date by which the water should comply with one or more prescribed classifications. The SWQO cannot be varied in less than 5 years unless, after consultation, the regulatory authority requests a review. Similar powers are available to the Secretary of State for Scotland. The importance of SWQOs is that the Secretary of State and the regulatory authorities are required to exercise their relevant pollution control powers (for example in setting discharge consents) so as to achieve the objectives, so far as practicable.

4.43 The NRA has recently published its proposals for setting SWQOs (see box 4.7). It envisages SWQOs for individual stretches of water which would consist of one or more use-related objectives and corresponding quality standards, any standards set by EC directives which apply to the waters in question, and dates by which each of the standards is to be met. It holds open the possibility that SWQOs should also incorporate targets related to a general classification. The use-related objectives proposed by the NRA cover not only what are traditionally considered as uses of water (irrigation, potable supplies, water contact activities, fisheries and the like) but also basic amenity (as a measure of aesthetic acceptability), general ecosystem (based on an ecological quality index derived from RIVPACS predictions) and special ecosystem (to take account of the special characteristics of sites of special scientific interest and national nature reserves).
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4.44 We agree with the NRA that one element of the statutory objectives should be couched in terms of the desired biological state of the waters. We have already recommended movement towards a biological classification scheme as the basis of future general descriptions of river and canal quality. We recommend that this classification should be used to set a biological SWQO. We see no need to develop an additional SWQO which combines chemical and biological criteria in a general classification in the manner which has been discussed by the NRA. In order to achieve the biological quality objectives, the regulators would set discharge consents in terms of chemical and other determinands. These would be designed to ensure that pollution from the discharges did not prevent the desired objective from being achieved. As discussed in paragraph 4.28, more determinands may be needed than are usually included in consents at present.

4.45 Because each use or potential use of a stretch of water is likely to require its own objective, we agree with the NRA that it will be appropriate to set more than one SWQO for many stretches of water. A mechanism will therefore be needed for resolving the inevitable conflicts which will arise between competing uses. Some will be relatively simple to settle, for example by adopting the most stringent standards as a basis for pollution control. In other cases, it is especially important that the selection of objectives should be open to debate and a matter of public record.

4.46 The discussion hitherto has been largely in terms of flowing waters but similar arguments apply to standing waters. We agree with the NRA's proposal that quality objectives be set for standing waters above 0.4 hectares so that deterioration in their quality can be prevented or reversed. These objectives could include the classification referred to in paragraph 4.39 above.

The setting of statutory quality objectives

4.47 We discuss in chapter 9 the adoption of a long-term aim of progressively reducing reliance on the environment to process wastes. This will call for demanding SWQOs and tighter discharge consents. Nevertheless a balance must be struck between the costs to be imposed on polluters and the improvements expected in river quality. Some general guidelines are needed in order to avoid a process of special pleading, discharge by discharge. It will be necessary to establish the BPEO for polluting processes, in the light of what is currently practicable, and to develop what the Commission's 10th Report called the Best Environmental Timetable for achieving it. The application of BATNEEC under the Environmental Protection Act 1990 provides a means of implementing the required improvements for some industrial processes and the concept behind it could be extended further. The approach will need to take into account the particular circumstances of each river and the pollutants to which it is subject. A view must be taken of the timescale over which existing processes must be upgraded and the extent to which the additional costs of applying Best Available Techniques are justified by the anticipated environmental improvement.

• 4.48 The NRA proposes that SWQOs should set targets for a period of three to five years ahead. The time needed to obtain significant reductions in the pollutants affecting the worst rivers may, however, be very long. The Mersey Basin campaign, for example, is continuing over some 25 years. The NRA would use SWQOs as a means of gradually tightening discharge consents over such a period until the desired improvements had been achieved. It is, however, misleading to assume that gradual improvement will always be appropriate. Many processes have only limited scope for gradually improving the quality of their discharges: significant improvements may require step changes in process control or technology. In these cases, it may be more economical and more environmentally beneficial to tighten, in one operation, the controls on the most polluting discharges to the extent necessary to achieve the ultimate target state of the river. In some cases, such an approach may call for a longer period than five years for the achievement of the SWQO. These factors emphasise the importance of setting SWQOs in a framework which enables longer term plans to be developed. We consider that catchment management plans, which we discuss in chapter 9, are the appropriate means for doing this.

4.49 A clear statement by the Government of how its wider pollution policies are to be taken into account in setting SWQOs would also be useful in settling conflicting priorities. In some
The NRA's proposals, (which may be modified following consultation), suggest that three elements might be included in SWQOs. These are (i) requirements to safeguard specific uses of water, (ii) requirements of relevant EC directives (such as that on the quality of surface water for drinking) and (iii) possibly a general purpose classification scheme (see box 4.4). Overall attainment of a SWQO would require compliance with all its individual components by a specified date.

The specific uses which the NRA envisages protecting by SWQOs are: basic amenity, general ecosystem, special ecosystem, salmonid fishery, cyprinid fishery, migratory fishery, commercial harvesting of marine fish and, as a separate class, shellfish for public consumption, water contact activity, abstraction for potable water supply, and industrial and/or agricultural use. Most of these are fairly familiar but three may require explanation. The objective of 'basic amenity' is designed to stop waters from becoming a nuisance and is a test of aesthetic acceptability. 'General ecosystem' is intended to promote and protect life dependent on the water and could be defined by means of an Ecological Quality Index (EQI). 'Special ecosystem' would incorporate standards required for sites with particular management needs, such as SSSIs.

Following consultation, Regulations have to be made setting out the criteria needed to incorporate the proposed uses in SWQOs. Only when the Regulations are in force can the Secretary of State actually set SWQOs. Some Regulations have already been made giving effect to requirements of EC directives. Notice must be given allowing at least three months for objections or representations. Having considered these the Secretary of State sets a SWQO by serving notice on the NRA specifying, for each identified stretch of water, which of the relevant classifications should be met by and after a specified date.

A table prepared by the NRA showing the envisaged application of SWQOs to a river catchment is reproduced below:

<table>
<thead>
<tr>
<th>Name of River</th>
<th>Name of stretch</th>
<th>Length (km)</th>
<th>NRA Class</th>
<th>Use-related Class (URC)</th>
<th>EC Class (BEC)</th>
<th>TC</th>
<th>URC</th>
<th>EEC</th>
<th>Overall Compliance</th>
<th>Components of the Statutory Water Quality Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>First River</td>
<td>Upper</td>
<td>3.0</td>
<td>B</td>
<td>B</td>
<td>None</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Basic Amenity, General Ecosystem, Potable Water Supply</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>4.5</td>
<td>C</td>
<td>C</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tributary</td>
<td>Upper</td>
<td>1.9</td>
<td>uc</td>
<td>uc</td>
<td>None</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Basic Amenity, General Ecosystem, Potable Water Supply</td>
</tr>
<tr>
<td></td>
<td>Upper Middle</td>
<td>8.0</td>
<td>A</td>
<td>B</td>
<td>ff</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Middle</td>
<td>7.0</td>
<td>B</td>
<td>B</td>
<td>ff</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>4.0</td>
<td>C</td>
<td>C</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next River</td>
<td>Upper</td>
<td>4.0</td>
<td>uc</td>
<td>uc</td>
<td>None</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Basic Amenity, General Ecosystem, Potable Water Supply</td>
</tr>
<tr>
<td></td>
<td>Upper Middle</td>
<td>5.5</td>
<td>A</td>
<td>B</td>
<td>None</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Middle</td>
<td>8.0</td>
<td>B</td>
<td>B</td>
<td>None</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>11.0</td>
<td>E</td>
<td>C</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key:
A - NRA Class A    ba - Basic Amenity
B - NRA Class B    ge - General Ecosystem
C - NRA Class C    sf - Salmonid Fishery
d - NRA Class D    cf - Cyprinid Fishery
e - NRA Class E    pw - Potable Water Supply
uc - Unclassified

UPPER CASE DENOTES A CURRENT FAILURE
cases, EC directives or binding international agreements (eg to clean up coastal discharges) may leave little freedom of choice. More complex cases (eg the reduction of acid emissions to the atmosphere) could be dealt with by a BPEO approach.

4.50 We discussed with representatives of the Netherlands Government the third National Policy Document on Water Management which contains a detailed analysis of the difficulties faced by that country in all aspects of its water policy. As well as a clear exposition of the problems, the document sets out specific targets, with timescales and broad strategies for their achievement, and the programmes by which the targets can be met. The programmes are described within the policy context to which they belong, final and interim goals are identified and, where possible, quantified, and the financial consequences are spelt out. We believe that such an approach gives a coherence to water policy which has sometimes not been discernible in the UK but which could help to ensure that water quality issues receive an appropriate degree of priority in areas of decision-making not at first sight related to the water environment. We recommend that the Government should draw up a water policy plan for the UK, setting out appropriate targets as well as timescales and means of reaching them.

4.51 We referred in paragraph 4.42 to the Government’s wish to eliminate class 4 and reduce class 3 river lengths. The 1990 river quality survey for England and Wales shows that these lengths are predominantly in the North-West (especially the Mersey basin), Yorkshire and, to a lesser extent, the Midlands. The major campaign to clean up the Mersey has already resulted in some improvements as we learned during our visit to the North-West. We recommend that, as a priority, ways of improving the remaining class 3 and 4 stretches should be identified, discussed with those responsible and costed so that action plans can be agreed to improve them over a realistic but challenging timescale. At the same time, everything should be done to prevent deterioration of high quality waters. The SWQOs for class 3 and 4 rivers should be set so as to achieve the targets in the action plans. The plans should be made public and progress monitored.

4.52 The changes in methods of classification we have recommended will mean that UK waters are described in a way which relates more closely to their natural potential than at present, and that firm, costed targets for their improvement are set. The new methods may reveal a less satisfactory state than has been previously indicated in river quality surveys; but we believe they will enable water quality managers to identify and remedy the effects of pollution which the present scheme obscures.
CHAPTER 5
GROUNDWATER

Introduction
5.1 Some types of soil and rock have pores and fissures which are capable of holding water. Sandstone, chalk and limestone formations in particular can become saturated with water which percolates through the rock. Such formations are termed aquifers. Water enters aquifers at locations where the rock formations constitute the land surface or are overlain by permeable soils. At such locations aquifers are described as unconfined (figure 5.1). Near the surface, in the soil moisture zone, water may be lost by evaporation. Deeper into the aquifer, in the unsaturated zone, the proportion of water to air in the gaps and pores increases until the saturated zone is reached at the water table. Water tables in unconfined aquifers respond to seasonal fluctuations in recharge, being normally high in winter and low in summer. Where aquifers are overlain by clay or other impermeable rocks or soils they are termed confined. At such places local rainfall will not percolate directly into them. Confined aquifers are generally recharged through an unconfined outcrop. As water percolates through the soil and rock of an aquifer its purity may improve because solids and micro-organisms tend to be filtered out and organic contaminants to break down. However, reactions between the soil, rock and percolating water may increase the content of dissolved solids. If the soil or rock is polluted, the groundwater itself can become polluted.

Distribution and use of groundwater
5.2 In terms of water capacity, the two principal aquifers in Britain are the Cretaceous chalk of southern and eastern England and the Triassic sandstone of the Midlands and north of England. Regionally and locally important aquifers occur in greensand, various limestones, sandstones associated with coal bearing rocks and in gravel deposits (see figure 5.2)1.

5.3 The geology of an aquifer affects both the rate of flow of groundwater and its chemical composition. Rates of flow vary considerably depending on the permeability of the rock and whether or not it is fissured. Coarse-grained materials with large interconnected pores, such as gravels, have a high permeability; water may travel relatively quickly, residing only for a few days or weeks in the aquifer before being abstracted or flowing into a river. Fine-grained deposits, such as chalk, have lower permeabilities and some groundwater may reside within the aquifer for years or even centuries before it is discharged or abstracted2. For example, it has been estimated that 85% of the recharge water in the chalk of the Berkshire Downs moves vertically at a rate of only about one metre a year. Pollution of land above a chalk aquifer by substances which are not readily degraded may thus take some time to affect the quality of abstracted groundwater. Movement of groundwater below the water table is principally through fissures; hence boreholes in chalk aquifers can still give high yields2 (see plate 11).

5.4 The volume of water in aquifers in England and Wales is estimated to be about 16,000 million cubic metres (m³), of which the major part is located in deep aquifers subject to little natural movement in or out. This compares with a figure of about 4,000 million m³ for the total volume of standing surface water in England and Wales. By contrast the total volume of standing surface water in the UK is about 40,000 million cubic metres3. The accessible groundwater resource is estimated to be about 1,500–2,500 million m³ and the annual natural recharge of this resource nearly 10,000 million m³. The average residence time is thus a little more than two months. Groundwater abstractions total about 2,000 million m³ annually; most of the remaining 80% of the annual recharge ultimately supplies the base flow of rivers4. The contribution of groundwater to the base flow of rivers is particularly significant in areas such as the chalk catchments of southern England. The River Itchen in Hampshire, for example, has a groundwater...
component of 75–90% of the total annual flow. Seasonal streams, fed largely by groundwater in chalk areas, reflect the fluctuation in height of the water table. When the water table is high in winter and spring it feeds the streams, which dry up when the water table falls in the summer and autumn.4

5.5 The quality of water flowing through an aquifer is affected by the filtration of solids and microbes and by the dissolution of soluble substances from the soil and rock. For example, groundwater in chalk aquifers is typically hard and alkaline, because it is rich in calcium salts. The influence of geology on the quality of groundwaters is described briefly in Box 5.1.

**Box 5.1 Geology and Groundwater Quality**

Groundwater from limestone and chalk aquifers is hard, because it contains high concentrations of calcium and magnesium salts dissolved from the rock, and slightly alkaline. Sandstones tend to yield soft water with little dissolved solids content. Occasionally waters from sandstones contain sufficient quantities of iron to colour them brown. Groundwater which has passed through peat or coal can contain high levels of iron and sulphides, colouring the water brown and rendering it corrosive. Very deep groundwater, whether in limestone or sandstone, may be saline. In the north of the Cheshire basin, for example, freshwater, usually less than 300m in depth, rests on ancient salt water. Groundwater in aquifers near the coast may also become saline due to intrusion by seawater. Most groundwater, except in very shallow aquifers, is free from viruses and bacteria, as the filtering action of the aquifer leaves few nutrients in the water for their growth as well as removing the microbes themselves. It is unusual for bacteria to spread more than 30 metres from a source of pollution except in freer flowing gravels and fissured aquifers, where bacteria have been known to spread several kilometres.
Figure 5.2 Outcrops of the principal regional aquifers, with boundaries of NRA regions in England and Wales and River Purification Authorities in Scotland superimposed.
Chapter 5

5.6 Groundwater is an important source of water for abstraction. Across the European Community as a whole about 70% of public supply is obtained from groundwater sources. In England and Wales about one-third of total demand is met from groundwater sources, although the proportion varies considerably from place to place. About 75% of supply in the area covered by the Southern Region of the NRA comes from groundwater. Some localities, here and elsewhere, are entirely dependent on groundwater. In Scotland and Northern Ireland, where there are abundant supplies of good quality surface water, less than 5% of public supplies are provided by groundwater sources, though they can be locally important. The rest of this chapter is based on the experience of groundwater use in England and Wales, although the principles and conclusions drawn apply generally. Groundwater is an important source of supply for private and industrial abstractors, being valued by industries such as food processing and brewing, where a consistent quality of water throughout the year is required. It is sometimes used for livestock watering, irrigation and by fish farms.

Artificial recharge

5.7 Since the 19th century, artificial recharge schemes have been used to supplement water storage for public water supplies, especially where these are vulnerable to major, unpredictable pollution incidents. Examples of such schemes are described in box 5.2. Recharge schemes have also been used for maintaining water tables to preserve wetlands and as hydraulic barriers to groundwater pollution, for example from saline intrusion. In Britain, river water is generally used for artificial recharge. The water is filtered and treated before introduction to the aquifer. Care has to be taken to prevent chemical or biological reaction between recharge water and the indigenous groundwater leading to the precipitation of mineral salts or encouraging bacterial growth. The European Community's groundwater protection directive (80/68/EEC) requires member states to issue special authorisations for artificial recharge schemes on a case by case basis. Such authorisations can be granted only where there is no risk of pollution or alteration of

<table>
<thead>
<tr>
<th>BOX 5.2</th>
<th>AQUIFER RECHARGE SCHEMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the 1880s and 1890s experimental recharge schemes, long since discontinued, were set up in the Thames basin. In 1953, with saline intrusion affecting groundwater in Essex and Kent and groundwater levels dropping, three public supply boreholes in the Lee basin were used for recharge experiments. More than three billion gallons of treated water from the river Lee were injected over four years. The quality of the borehole water improved and the annual fall in groundwater was reduced. The Lee Valley Artificial Recharge Scheme, involving six wells and seven boreholes, was developed in the 1970s. This scheme, still in use, helped to meet demands during periods of drought in the 1980s.</td>
<td></td>
</tr>
<tr>
<td>Thames Water is promoting a scheme to recharge a chalk aquifer in the north of London, to store water for up to eight years. Drinking water will be pumped into the aquifer, which can hold up to 150 million gallons locally, about four times as much as can be held in the company's largest reservoir, the Queen Mother reservoir at Heathrow. The project will cost about £7m; it would cost about £1bn to build a reservoir of equivalent capacity.</td>
<td></td>
</tr>
<tr>
<td>In 1981, the then Severn-Trent WA introduced a pilot scheme to recharge the Triassic sandstone aquifer with water taken from the river Severn. The proposal was to abstract water from the river Severn for about 90% of an average year and discharge the treated water to the aquifer through a recharge borehole. The water, recovered from another borehole, would supply two million gallons a day of drinking water. The advantages identified by Severn-Trent from the pilot study were that the system was relatively cheap to construct and maintain, had little or no effect on the environment and took up only a small area of land. However, the quality of the treated water used to recharge the aquifer was very critical. The pilot scheme was discontinued in 1986 because the constraints this quality requirement placed on the treatment works were hard to overcome and because it was not felt that groundwater recharge had a role to play in the water resources of the region in the medium term.</td>
<td></td>
</tr>
</tbody>
</table>
the quality of groundwater. They may last for a period of up to four years and are subject to renewal. In England and Wales, aquifer recharge schemes require licences for abstraction and discharge from the NRA.

Pollution

5.8 Pollutants reaching an aquifer are liable to spread gradually through it in a manner which depends on the nature of the pollutant and of the aquifer. Once soluble chemicals, such as nitrate, have reached an aquifer they move in the direction of the groundwater flow. Poorly soluble liquids which are denser than water, for example trichloroethene and other chlorinated solvents, sink below the water table and may flow separately along low permeability layers encountered at depth in the aquifer (see figure 5.3). The flow direction may not necessarily coincide with that of the overlying groundwater. Petrol, which is less dense than water, spreads out over the surface of the water table and flows in the direction of the groundwater.

![Figure 5.3 Migration of a contaminant through an aquifer](image)

5.9 Pollutants can reach groundwater by the deliberate discharge of effluents into aquifers, for example, through a borehole, soakaway or well. Between 1907 and 1974 about 320 million litres of chloride-rich water were pumped from the Tilmanstone coal mine in east Kent to lagoons, from where most soaked away into the chalk aquifer. About 15% was dissipated by stream flows but the rest has remained in the aquifer, contaminating an area of about 27 square kilometres with saline water at salt concentrations of between 200 and 5000 mg/l. Using treatment methods which enhanced the purifying capacity of the aquifer it was expected to take some 30 years to produce sufficient improvement in quality to enable the aquifer to be used for public supply. Recently pressure on water resources in Kent has prompted the Folkestone and District Water Company to consider using desalination techniques to treat some 10 million litres/day of water abstracted from the aquifer.

5.10 A more widespread threat to groundwater stems from percolation through the soil of substances contaminating the overlying ground. These may come from point sources such as landfill sites, contaminated industrial sites or septic tanks, or from diffuse sources such as pesticides spread on farmland. In 1980, contamination of a borehole used for public supply by a leaking sewer and a polluted stream, both of which passed within 8 metres of it, led to an outbreak of gastroenteritis in Yorkshire. In its evidence to us, the Public Health Laboratory Service (PHLS) reported that a recent survey of private boreholes, springs and wells in the Leeds and Truro areas found contamination by coliform bacteria in about a quarter of the boreholes and about two-thirds of the springs and wells. These are usually important local water sources, often supplying isolated farms and houses which also tend to rely on cesspits or septic tanks for the disposal of domestic sewage. Responsibility for monitoring the quality of these supplies rests with local authorities, which have powers to require improvement to private supplies if they are
Chapter 5

contaminated. The PHLS survey suggests that many users may be at risk from contaminated supplies. We recommend that the Government consider with local and public health authorities whether adequate monitoring is being carried out and adequate advice offered to users of private supplies.

5.11 Over-abstraction can also lead to groundwater pollution. For example, coastal aquifers with submarine outcrops are liable to saline intrusion if they are subject to over-abstraction. To protect against this it is customary to manage abstraction, by pumping boreholes near the sea in winter, when the water table is higher, and those further inland in summer.

Monitoring

5.12 Groundwater has been monitored by taking samples from abstraction boreholes, supplemented by monitoring of water from observation boreholes. Other than this there is little systematic monitoring of groundwater quality and there is no groundwater equivalent of the regular national survey of surface water quality. Nevertheless, it has been possible to build up a picture of the natural concentrations of the main inorganic ions, such as carbonate, sulphate, chloride, calcium and magnesium, found in groundwater, and of the trace elements in the major aquifers. Monitoring of organic chemical pollutants, particularly solvents and pesticides, in aquifers has only recently become common and there is still much work to be done on devising adequate sampling procedures for these pollutants at the concentrations found in groundwater.

The Institute of Hydrology and the British Geological Survey (BGS) publish data annually on groundwater resources in England and Wales, based on the 175 observation boreholes of the National Groundwater Archive, but BGS does not systematically collect and publish quality data. The Archive relates mainly to boreholes which provide public supply, though records from any borehole greater than 50 metres deep are required to be lodged at BGS.

5.13 A report by Halcrow and Partners for the Department of the Environment in 1988 commented that monitoring of groundwater quality required substantial improvement. It recommended a national network of observation points and suggested the NRA could be responsible for collating and archiving the data. We understand that the NRA has considered how a national groundwater sampling network might operate but has no specific proposals to set one up at present. We support the Halcrow report recommendation, which we consider should be implemented in Scotland and Northern Ireland as well as England and Wales, with the appropriate territorial authorities taking the lead. The Halcrow report drew attention to the need to consider details of the network, including the number of observation points and the determinands to be measured. We have not investigated these matters in detail. We consider it desirable for the network to give a representative picture of the state of groundwaters in aquifers throughout the country. Coverage should include aquifers which are known to be contaminated as well as those whose quality is believed to be good; it should not be restricted to aquifers used for abstraction purposes. Determinands to be measured should be chosen so that successive surveys can indicate trends in the main potential pollutants, such as nitrate, pesticides, solvents and landfill leachates. We note in paragraph 5.15 that boreholes are themselves potential sources of contamination. Notwithstanding the assurances we received from the NRA about the lack of evidence of pollution from boreholes, we consider it would be prudent, as well as cost-effective, to rely where possible on existing boreholes for the national network. Subject to the need to achieve representative coverage, the construction of additional boreholes intended solely for the national monitoring network should be kept to a minimum.

5.14 Research has provided some information on the nature and extent of groundwater pollution. For instance, surveys of aquifers under urban and industrial areas have revealed extensive pollution from organic solvents (see figure 5.4). Trichloroethene and tetrachloroethene have been found in water abstracted from boreholes in areas where engineering and degreasing operations have been carried out. In an extensive survey of the Birmingham aquifer, trichloroethene, a metal and plastic degreaser, was found in about three-quarters of borehole samples at concentrations in excess of 0.1 μg/l and, in nearly a third, above 100 μg/l. Other metal degreasing agents or dry-cleaning solvents were also found contaminating borehole samples, often
The chlorinated solvents most commonly used in the UK are trichloroethylene (TCE), tetrachloroethylene (PCE) and trichloroethane (TCA). TCA, the least toxic of these solvents, was introduced in 1965 as a replacement for the other two compounds in dry cleaning. Its use has grown steadily since then, while consumption of TCE and PCE has declined since the mid-1970s. Annual consumption of the three solvents (based on figures provided by various suppliers) is now between 30,000 and 33,000 tonnes of TCA, about 29,000 tonnes of TCE and 13,000 tonnes of PCE.\(^a\)

A recent survey\(^a\) of the Birmingham aquifer has revealed the presence of several chlorinated solvents at concentrations in excess of the EC Drinking Water Directive guide value of 1.0 \(\mu g/l\) and in many cases exceeding the World Health Organisation (WHO) guideline values for these substances, which vary between 10 and 30 \(\mu g/l\). TCE, which has had a widespread use in the UK as a metal degreaser and, until recently, in dry cleaning, was the major contaminant found. TCE concentrations were higher than 0.1 \(\mu g/l\) in samples from 72% of the 59 private supply boreholes investigated and above the 30 \(\mu g/l\) WHO guideline value in water from 40% of the sites; samples from 30% of the boreholes, most of them at metal industry sites, contained more than 100 \(\mu g/l\) TCE, in one case 5,500 \(\mu g/l\). TCA concentrations were above the 10 \(\mu g/l\) WHO guideline limit at 13% of the sites and above 30 \(\mu g/l\) at 8%: the highest concentration found being 780 \(\mu g/l\). PCE concentrations exceeded the 10 \(\mu g/l\) guideline at 4% of the sites, the highest concentration (460 \(\mu g/l\)) being found at a laundry borehole.

at levels in excess of WHO guidelines for drinking water (see box 5.3). The authors of the survey report observed that the solvents detected had often been used in the industrial sites where the sampling boreholes were located. The greatest solvent contamination was generally observed where the aquifer cover was thin or permeable but a few confined aquifers also contained high concentrations. The route of contamination could have been down the outside of the lining of poorly constructed abstraction boreholes or by direct disposal down disused boreholes, although there is no positive evidence to confirm this. Another possible contamination route may have been through disposal of solvents on or near the surface of the ground to allow them to evaporate, but with the result that some part of the solvents disposed of in this way percolated into aquifers. At Harwell research laboratory, waste solvents were disposed of during the period 1948–1977 by burial in shallow pits, an accepted practice at that time. This may have been the origin of groundwater contamination by chlorinated solvents at the Harwell site.\(^b\)

**Borehole construction**

5.15 Boreholes can be sunk for a variety of purposes, for example to test for the presence of groundwater, to monitor the depth or quality of groundwater or to abstract water. Planning permission from the local authority is normally required before a borehole can be sunk. If the borehole is to be used to examine the hydrology of an aquifer or to test the effect of abstraction on other water sources a written consent from the NRA is also required. With certain exceptions, for example for domestic purposes, if water is to be abstracted through the borehole an abstraction licence from the NRA is required. To maintain a picture of the location, type and effect of borehole abstractions, written notice of all proposed boreholes greater than 50 metres in depth must be sent to the British Geological Survey (BGS) and a copy of the record of their use submitted. BGS officers have statutory powers to sample boreholes and inspect records. Where boreholes are being sunk in contaminated land, NRA groundwater officers inspect the boreholes and their operation. The NRA informed us that it knew of no aquifers being polluted as a consequence of the poor construction or siting of a borehole. For monitoring near landfill sites, DOE recommends that a competent hydrogeologist should carry out a survey to indicate the number, location, mode of construction and depth of boreholes required. Waste regulatory authorities may lay down requirements for the number and location of boreholes to monitor groundwater around a landfill site as part of the conditions of the site licence (see paragraph 7.9).\(^b\)
Groundwater protection

5.16 Few public supply boreholes have had to be abandoned because of pollution. The quality of water abstracted from boreholes remains high. This should not give rise to complacency, however. The surveys referred to in paragraph 5.14 demonstrate that aquifers may be polluted and that the mechanisms giving rise to pollution are not well understood. In the absence of any national groundwater quality survey, there can be no confidence about the state of groundwaters across the country. Sustainable use of groundwater is often thought of solely in terms of limiting over-abstraction. Protection from pollution is also essential to maintain its sustainability. In chapter 9 we propose a policy of progressive reduction in discharges of polluting wastes. In the case of groundwater, however, because of its limited capacity for self-purification and the difficulty of decontaminating aquifers once they have become polluted, we recommend that elimination of all polluting impacts should be pursued as an immediate policy aim rather than a long term goal.

5.17 Pollution threats to groundwater come both from discharges into aquifers, whether deliberate or otherwise, and from activities which, while not involving discharges, risk contaminating the soil overlying aquifers. Moreover, even if all such activities were immediately halted, there would still remain, from past activities, a legacy of contaminated land that would continue to threaten groundwater. A range of statutory powers exists for addressing all these pollution threats but they vary in effectiveness and in the extent to which the regulatory authorities have been prepared to make use of them. Recent events, both in this country and in the European Community, which we discuss below, indicate that greater attention is now to be paid to groundwater protection, a development which we warmly welcome.

5.18 Discharges of effluents into groundwater, whether directly, through shafts or boreholes, or indirectly, for example through soakaways, are capable of control through the well-established
system of discharge consents. The EC directive on groundwater protection (see appendix 4), agreed in 1980, prohibits discharges of many substances to groundwater and restricts discharges of many others. A survey of public registers carried out for us by the NRA identified only a handful of consented direct discharges to groundwater, suggesting that this is not normally seen as an acceptable route for disposal of effluents. Indirect discharges are more numerous and their regulation by the NRA regions and the predecessor water authorities appears to have varied. Some authorities have required consents for all discharges to soakaways near aquifers, for example from road drains and septic tanks; others appear not to have done so. The NRA is now proposing to apply consistent policies throughout England and Wales. It set out proposals in a recent consultation document on protection of groundwater, which we discuss in more detail below. We welcome this and consider that it should lead to a useful strengthening of control of direct and indirect discharges to groundwater. The Scottish Office told us that there were no plans to introduce a similar protection scheme in Scotland at the present time because of the lack of pressure on groundwater resources there.

5.19 Of greater concern as a pollution threat to groundwater is the effect of activities not involving discharges but which risk contaminating the soil overlying aquifers. The range of such activities is wide and regulatory controls are less well developed than for discharges. The town and country planning system offers a degree of control over new developments and changes of use. We note, for example, that the Secretary of State last year refused planning permission for construction of a waste incinerator near Doncaster because it risked pollution of the underlying aquifer. We comment in chapter 9 on ways in which the land use planning system could be strengthened to improve protection of water resources. Planning controls in general, however, come into play only when developments are proposed. They are therefore not suited to providing the flexible control over activities that is needed for pollution prevention. The licensing procedures for waste disposal sites enable some further controls to be exerted, for example to reduce the risk of leachate from landfill sites reaching groundwater. The powers we recommend in chapter 9 to enable the NRA and HSE to issue improvement and prohibition notices where there is a risk of pollution could help to reduce risks of groundwater pollution. Powers also exist for the Secretary of State to designate water protection zones where activities likely to result in water pollution can be prohibited or restricted. A designation order could give the NRA power to define the activities which are to be prohibited or restricted in the zone. An order could alternatively prohibit or restrict activities carried out without a consent from the NRA. These provisions, which have not been used to date, are potentially very powerful. Their use could do much to strengthen protection for groundwater. In its recent consultation document on protection of groundwater, the NRA expresses an intention of seeking designation of water protection zones. We welcome this. Similar, though separate, powers exist to designate nitrate sensitive areas to protect water from nitrate pollution. These powers are currently being exercised on an experimental basis, as we discuss in chapter 7.

5.20 Tackling the legacy of contaminated land which pollutes or threatens to pollute groundwater is a task which we consider has so far received inadequate attention. As we discuss in chapter 7, the Government, in response to a recommendation by the House of Commons Select Committee on the Environment, last year proposed the establishment of local registers of contaminative uses but it will take some time for these to be completed and the lack of base data will cast some doubt on their reliability. The NRA is drawing up a list of priority sites which threaten groundwater. Even if all such sites were identified, the remedial task would be far from easy. In some cases the sites will be in use and remediation could only be carried out with considerable disruption to the occupiers. Even when sites are not in use, remediation techniques for the variety of circumstances that can exist are not well established and can be very costly. Landowners may be unwilling to carry out work whose costs might be out of proportion to any economic benefit they may obtain. The Government offers developers derelict land grants to help with the cost of restoration; works to bring the land back into use will not always include complete removal of threats to groundwater, however.

5.21 There thus remains much to be done before it could be claimed that threats to groundwater quality were properly under control. Controls over discharges, direct and indirect, to groundwater are well established and should shortly be exercised in a more consistent and comprehensive
Chapter 5

fashion. Controls over activities which may contaminate land over aquifers are less well developed and haphazard in their operation. The problems of the legacy of polluted sites have scarcely begun to be addressed. Against this background, two recent developments indicate the problems are now receiving greater official recognition.

European Community policy

5.22 An EC directive on groundwater protection was agreed in 1980. It is concerned with pollution from point sources. Last November, EC Environment Ministers agreed a declaration on groundwater recognising the need to protect it against the full range of threats and proposing an action plan to be implemented by the year 2000 to protect and improve groundwater. Box 5.4 summarises the main points of the declaration. Measures proposed include surveying groundwater resources; controls over polluting activities; integration of groundwater protection policies into land use planning and into policy areas including agriculture and transport; remedial works; and the use of economic and financial measures. The declaration stresses the objective of sustainability, to be achieved through an integrated approach taking account of interactions between surface water and groundwater, between soil, air and groundwater and between environment policies and other policies. The EC Commission is charged with developing by mid-1993 proposals to implement the programme. We consider this declaration to be an important step towards developing comprehensive policies and programmes for protecting and improving groundwater quality. We urge the Government to make a positive contribution to this process.

UK policy

5.23 Meanwhile, the NRA has been working on proposals of its own for improving protection of groundwater. It inherited from its predecessor water authorities a variety of approaches to this including, in the Severn-Trent and Southern Regions, well developed aquifer protection policies. These were non-statutory documents setting out policies to prevent groundwater pollution, including identification of aquifer protection zones around abstraction sources, with increasingly severe policies as proximity to abstraction sources increased. Some policies were capable of implementation using statutory powers, others required co-operation with local authorities and landowners. The NRA has recently published proposals for consistent policies to protect groundwater throughout England and Wales. The proposals represent an important development of the policies inherited from the water authorities. Surveys will be carried out to prepare 'vulnerability maps' for aquifers depending on their geology, the nature of overlying soils and depth of unsaturated zones. These will enable three separate 'resource protection zones' to be identified – major aquifers, minor aquifers and non-aquifers. Different policies will apply to each. In addition, 'source protection zones' will be defined around abstraction sources. One zone will cover the entire catchment supplying the abstraction source. Where sources are located on unconfined aquifers, two tighter protection zones will also be defined. Detailed policy proposals have been developed indicating the degree of acceptability of a wide range of potentially polluting activities in each zone. Policies are designed not just to prevent pollution but also to protect against interference with the flow of water in aquifers. As with the earlier aquifer protection policies, to achieve its objectives the NRA will have to rely partly on co-operation with other authorities and landowners. It has, however, expressed an intention to seek designation of water protection zones where this can be justified.

5.24 The NRA's recent consultation document on water quality objectives suggests that the only objectives needed for groundwater relate to its use for water abstraction. We consider that this would not necessarily provide an adequate underpinning for the policy of pollution prevention that we advocate in paragraph 5.16. It needs to be supplemented by objectives which would safeguard the quality of rivers and lakes fed by groundwater and ensure that groundwaters are free of polluting inputs, regardless of the circumstances of their current use. We recommend that the NRA and its counterparts in Scotland and Northern Ireland seek to define such water quality objectives. These will provide a useful spur to the development of the national groundwater monitoring network referred to in paragraph 5.13.
Northern Ireland.

We therefore recommend that the will especially powers protection policies and above clean land. We Beyond authorities, the income be necessary should be encouraged to preserve the warmest groundwater and soil; to prevent further deterioration of contaminated groundwater and soil; to prevent long-term over-exploitation; and to replenish groundwater systems, where appropriate, to a sustainable level.

An action programme was proposed, to be prepared by the EC Commission by mid-1993, and including the following measures:

- mapping, characterisation and monitoring of groundwater systems;
- developing plans, where appropriate, to rehabilitate polluted groundwaters and soils and over-exploited aquifers;
- taking account of water management and protection policies in land use planning;
- introducing systems of permits, rules and codes of practice for water abstraction and for activities which could pollute water or soil, including those involving hazardous substances and waste disposal;
- improving administrative structures, where necessary, to promote integrated management of freshwater resources; and
- reducing the use of fertilisers and pesticides and replacing persistent and accumulative pesticides by degradable and less harmful products.

The new policies are to be supported by economic and financial measures, research programmes, education and training schemes and steps to improve public awareness. The declaration recognised the need to incorporate the policies into other relevant policy areas of the Community.

5.25 We warmly welcome the steps that are now in train to improve protection of groundwater. We do not consider that protection is justified only where there is an abstraction requirement. We therefore recommend that the approach the NRA is developing be extended also to Scotland and Northern Ireland. We believe valuable benefits will be obtained from the measures described above to survey aquifers in order to identify their vulnerability, to extend and develop aquifer protection policies and to make better use of the powers that exist to protect groundwater, especially powers to designate water protection zones. Improved consultation with other authorities, in particular local planning authorities, is also important. Aquifer protection policies will assist in this regard and we make further recommendations on consultation in chapter 9. Beyond this, we see a need for further work to address the problem of the legacy of contaminated land. We recommend that the Government seek ways of increasing the resources available to clean contaminated land in order to protect groundwater. This would be an appropriate use for the income from the charging scheme that we propose in chapter 8. In some locations it may be necessary for the NRA, and its counterparts elsewhere in the UK, to arrange for remedial work to be carried out. Where sites are in use or being redeveloped, however, occupiers and developers should be encouraged to carry out improvements, assisted where appropriate by public funds.
CHAPTER 6
EUTROPHICATION AND ACIDIFICATION

Introduction
6.1 Though very different in their causes and effects, eutrophication and acidification can both produce progressive, and sometimes severe, deterioration in environmental quality, including loss of species diversity, loss of amenity and problems for abstractors and other water users. Eutrophication, the term used to describe enrichment of water by plant nutrients, is a consequence of current agricultural practices and of the presence in water of sewage effluents. Acidification is caused mainly by emissions from fossil fuel power stations and vehicle exhausts. Both are the result of activities which are widespread in, and integral to, present-day society. Measures to reverse the two processes, or to remedy their adverse effects, may be very expensive.

EUTROPHICATION
Nutrient enrichment
6.2 The role of nutrients in determining the biological character of waterbodies is described in chapter 2. The availability of nutrients determines the rate of plant and algal growth and the biomass that they can achieve, on which the rest of the biological community in turn depends. Lakes and other water bodies can be classified according to their nutrient status, or trophic state. Ultra-oligotrophic describes an extreme state of nutrient impoverishment. Waters with increasing levels of nutrient availability are successively termed oligotrophic, mesotrophic, eutrophic and hypertrophic (a contraction of hyper-eutrophic, a term that is also sometimes used). Chapter 2 describes the typical character of such lakes. The process of nutrient enrichment is often called

| BOX 6.1 THE ROLE OF NUTRIENTS IN THE PROCESS OF EUTROPHICATION |

Algae and higher plants, which form the primary food source in the complex food webs in freshwater environments, need nutrients if they are to grow. For example, the diatoms, the green algae and the yellow green algae require 18 nutritional elements. Eight of these (hydrogen, carbon, oxygen, potassium, sodium, magnesium, calcium and sulphur) are usually adequately abundant in surface waters. Of the rest, nitrogen and phosphorus are critical as they are needed in substantial quantities and are not always readily available. The potential for plant and algal growth in a waterbody is often defined in terms of the amount of phosphorus and/or nitrogen present.

Plants, including algae, generally require about seven times more nitrogen than phosphorus by weight. The ratio of these substances in a waterbody is therefore important. If the ratio of nitrogen to phosphorus (N:P) falls below about 5:1, growth will be limited by nitrogen; if it is higher than 12:1, it will be phosphorus-limited. The N:P ratio of oligotrophic lakes is about 100:1 and that of eutrophic lakes about 10:1. Table 6.1 shows typical levels of phosphorus for the different trophic categories of lakes.

Criteria developed by the OECD for classifying the trophic state of lakes and other standing waters (see table 6.2) include measures of total phosphorus and of chlorophyll and transparency. Total phosphorus consists of phosphorus in particles, colloidal phosphorus, dissolved organic compounds of phosphorus and soluble inorganic compounds (orthophosphates). Chlorophyll is a green pigment, present in most higher plants and algae, that plays an essential role in photosynthesis, the process in which plants use solar energy to make simple carbohydrates from carbon dioxide and water. The concentration of chlorophyll in a water sample is a measure of the numbers of phytoplanktonic algae present.
eutrophication, a term which is used in relation to waters in any trophic state, not just to those which are already or are becoming eutrophic. To avoid confusion, we use the term nutrient enrichment to describe the process. Nitrogen and phosphorus are usually the nutrients which are the most critical in determining the trophic state of a waterbody (see box 6.1). Phosphorus is normally, though not always, the limiting factor in freshwaters, while nitrogen is usually limiting in marine waters.

6.3 Nutrients enter rivers and lakes from natural sources and a trophic equilibrium is maintained if the input of nutrients balances their output. Natural inputs are, however, frequently supplemented by inputs from agriculture, sewage effluents and some other sources such as fish farms. In its evidence to the Commission, the former NCC estimated that the background level of phosphorus in waters unaffected by sewage or other human activities might be between 0.005 and 0.01 mg/litre. Lund and Moss1 consider that a lowland river in Southern England might have, from agriculture and natural sources combined, a 'catchment background' level of phosphorus of about 0.02-0.05 mg/litre. The phosphorus concentration of a typical

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**BOX 6.2 NITRATE AND PHOSPHATE CONTENT OF SELECTED RIVERS**

<table>
<thead>
<tr>
<th>Nitrates mg/litre (as nitrogen)</th>
<th>Phosphates mg/litre (as phosphorus)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/P Ratio</td>
</tr>
<tr>
<td>Min</td>
<td>Mean</td>
</tr>
<tr>
<td>----</td>
<td>--------</td>
</tr>
<tr>
<td>R. Teith (Central Region, Scotland) upper</td>
<td>0.1</td>
</tr>
<tr>
<td>lower</td>
<td>0.2</td>
</tr>
<tr>
<td>R. Tyne (East Lothian) upper</td>
<td>2.7</td>
</tr>
<tr>
<td>lower</td>
<td>2.8</td>
</tr>
<tr>
<td>R. Tay at Perth</td>
<td>0.09</td>
</tr>
<tr>
<td>R. Cuckmere (Sussex) upper</td>
<td>0.8</td>
</tr>
<tr>
<td>lower</td>
<td>2.2</td>
</tr>
<tr>
<td>R. Stour (Kent) at Wye</td>
<td>4.0</td>
</tr>
<tr>
<td>R. Great Eau (Lincolnshire)</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Nutrient levels are low in the Upper Teith, which drains upland moor in the Central Region of Scotland. Downstream levels of nutrients in the Teith are also small, because agriculture in the lower reaches is not very intensive and population numbers are not high. Intensive agriculture, both improved grassland and arable, is practised over the entire catchment of the East Lothian Tyne; relatively high nitrogen levels near the source reflect this. The impact of a small sewage works in the lower reach of the Tyne can be seen in the higher downstream phosphorus content. The concentrations in the river Tay at Perth are intermediate between the previous two examples, with high run-off from mountain areas and intensive agriculture in the lowlands. The data for the chalk catchment of the river Cuckmere in Sussex indicate that geological differences are being masked by pollution from catchment land use, the pattern being similar to that for the river Tyne. Where these rivers have high N/P ratios (above 20:1) there is justification for assuming that eutrophication can be further increased by increases in phosphate loading. The exception is the river Stour below Wye which contains the sewage effluent from a large population and has a very high phosphorus concentration.

Source: NCC evidence to the Commission
treated sewage effluent is about 10 mg/litre. A ten-fold dilution of the sewage effluent would lead to a phosphorus concentration in the river of about 1 mg/litre, that is, between 20 and 50 times greater than the 'catchment background' level and perhaps 100 times greater than the 'natural' background level. In many rivers dilution of sewage effluents is much greater than 10:1. In some rivers in heavily populated areas, however, the dilution is less than that, particularly at times of low flow (see, for example, table 1.1 in chapter 1). Box 6.2 contains examples of nitrate and phosphate levels in selected British rivers.

6.4 Limited enrichment of nutrient-poor waters may be welcome from some perspectives, bringing an increase in the abundance and variety of plants, fish and other animal life. However, this may be at the expense of plant or animal species that are found only in nutrient-poor waters. The Forth River Purification Board pointed out in its evidence to the Commission that some fish populations have been lost or are threatened by nutrient enrichment. The vendace has been lost from Mill Loch and Castle Loch and the smelt from Rostherne Mere, the loss in all cases being attributable to enrichment. Further rare and endangered species are found in oligotrophic lakes and are sensitive to enrichment, see for example box 6.3 on the Arctic charr. The NCC identified over 150 freshwater sites of special scientific interest (SSSIs) which were adversely affected by enrichment, many in nutrient-poor upland areas. In its evidence to the Commission, it drew attention to Loch Shiel, which was designated an SSSI as a 'good example of a large, deep, oligotrophic fjord lake which has been very little affected by human activities'. It contains plant

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**BOX 6.3 ARCTIC CHARR IN WINDERMERE**

Arctic charr (*Salvelinus alpinus*) is found in several sites in Scotland, Wales and Ireland but in England it is restricted to the Lake District. It is usually regarded as a glacial relict, one of a small number of species which now occur in land-locked lakes but which at one time migrated freely to and from the sea.

In Windermere, the largest natural lake in England, there are at least four genetically distinct races of Arctic charr, two in the north basin and two in the south basin. In both north and south basins, one of the two races breeds in the spring, the other in the autumn.

The Institute of Freshwater Ecology has carried out long term studies at its Windermere Laboratory, which indicate that eutrophication may be an important factor in the observed decline in numbers of charr in the south basin of the lake.

Records of charr catches held by the Institute go back to 1939; measurements of lake nutrients have been made since 1945. In the north and south basins, changes in the mean winter concentrations of nitrate have been similar, the concentrations changing very little until about 1970 and increasing gradually thereafter, during the seventies and eighties. There are marked differences, however, in the changes in phosphate concentrations which have occurred in the two basins; these differences can be related to differences in the phosphorus input from sewage. In the south basin, there has been an approximately 20-fold increase in the concentration of soluble phosphorus since the late 1940s, to over 20 μg per litre. In the north basin the concentration is below 10 μg per litre. Over the same period, catches of Arctic charr in the south basin have declined.

Nutrient enrichment is not directly harmful to charr. In moderation it is beneficial because of its effects on primary production but the benefits are outweighed with increasing enrichment by the de-oxygenation of the lower layers of the water which occurs in late summer and autumn. Juveniles of the spring-spawning populations are especially vulnerable to de-oxygenation of the lower layers when surface water temperatures are high. For example, in the south basin of Windermere during August 1988, there was only a narrow zone of water (less than 10 m in depth) suitable for the fish between the surface water, which was above the charr's preferred maximum temperature (16°C), and deeper water which had insufficient oxygen for survival.

and animal communities typical of a waterbody of this type but fish farming is threatening to increase nutrient levels and may negate the reason for site selection. The NCC argued that, to conserve the diversity of freshwater systems, ‘this less insidious form of eutrophication must be reversed.’

6.5 The main focus of public concern over nutrient enrichment has been on the more extreme cases of eutrophic and hypertrophic lakes, reservoirs and other water bodies. Although a small degree of enrichment of nutrient-poor waters can increase diversity of species, heavy enrichment of waters can have the opposite effect. Hypertrophic waters are typically turbid and choked with

### BOX 6.4 CYANOBACTERIA

There is a seasonal succession of dominant organisms in freshwater which might typically be diatoms in the spring, green algae in the summer and Cyanobacteria (blue-green algae), including nitrogen-fixing species such as *Anabaena*, in the autumn. Certain Cyanobacteria that predominate in eutrophic waters produce toxins that are not easily destroyed by boiling or by treatment with alkali or acid. The toxicity of a single bloom may fluctuate rapidly.

The growth rate of Cyanobacteria is accelerated by increases in temperature and in day length and by near surface stratification of the waterbody. The mild winter and spring of 1989/90 were thought to have been significant factors in the early appearance of algal blooms in Cornwall, Devon, Staffordshire and Nottinghamshire. Many Cyanobacteria move to the surface to photosynthesise and descend after having produced carbohydrates but they may remain at the surface as a scum, whose persistence depends on weather conditions and the physical nature of the waterbody. Cyanobacteria do not normally occur in well flushed waterbodies, with replacement times of less than 5-10 days, nor in the open channels of rivers.

During autumn 1989 the NRA surveyed 915 waterbodies to establish the extent of Cyanobacteria blooms throughout the UK. Cyanobacteria were the dominant organism in 594 of the waters examined. The densities of Cyanobacteria in 169 waterbodies, mostly in the Anglian, North West, Severn-Trent and Wessex regions, were high enough to warrant alerting owners and local authorities. Toxicity tests were positive for 53 out of 78 waterbodies.

Rutland water attracted much attention; it is one of the largest artificial lakes in Europe, provides drinking water supplies for more than 1 million people and is used by at least 10,000 people a day at weekends for recreation. In September 1989, a scum several inches thick developed for 18 miles around the shoreline and 15 dogs and 20 sheep which allegedly drank scum-contaminated water, or in the case of the dogs licked it from their fur, died. There were no reports of fish, bird or other animal deaths. A few people, mainly sail-boarders but also children throwing stones, who came into contact with the scum-contaminated water, developed skin irritation, blistering around the mouth or gastrointestinal. At a second site, Rudyard reservoir, Army cadets who were canoeing and swimming developed similar symptoms (and atypical pneumonia) following contact with the scum.

Water abstracted for supply may need special treatment, for example with granular activated carbon, to remove toxins. In addition, the polysaccharides associated with the early stages of an algal bloom can cause foaming when the water is boiled.

A Task Force set up by the NRA in December 1989 concluded, *inter alia*, that:

- it was not possible at present to control the production of toxins but it was possible to control the formation of blooms;
- all Cyanobacteria blooms should be considered toxic and treated accordingly;
- contact with blooms and especially with scum should be avoided;
- algicides should not be used because of uncertainty about their persistence and the toxicity of their breakdown products and also because some Cyanobacteria release toxins when they die.
algal blooms. Oxygen levels fluctuate and anoxic conditions may eventually predominate at night, especially in hypertrophic shallow lakes. Animal and plant diversity declines and conditions may favour the growth of potentially toxin-producing species, for example of Cyanobacteria (also known as blue-green algae). Such waters are of reduced conservation and amenity value and may sometimes have to be closed to the public because of risks from toxins. Abstracted water is likely to be tainted, can contain high concentrations of iron and manganese and can be used for potable supply only after special treatment.

6.6 In recent years problems caused by Cyanobacteria (see box 6.4) have attracted much attention. Mild winters and stable conditions of temperature, wind and water favour the production of blooms of these organisms. Scums may accumulate on lake shores. Some Cyanobacteria release toxins; people coming into contact with the scums have sometimes become ill, while a number of animals have died. An NRA task force convened to investigate and advise on blue-green algae concluded that, until rapid analysis was available, all blooms of Cyanobacteria should be considered potentially toxic and treated accordingly, if necessary restricting public and animal access to affected waters. The task force also recommended priorities for further research, including work on the toxicity of Cyanobacteria, on improved methods for detecting the toxins at low concentrations in water and on the possibility of the toxins bioaccumulating through the food chain.

6.7 Nutrient levels in water are not the only factors influencing the growth of algae and other plants. The flow rate of the water, the geology of the catchment, the abundance of grazing zooplankton and other factors will also influence the way in which the ecosystem responds to nutrient enrichment. The difference between flowing and standing waters is of particular significance. In the latter, heavy growths of algae and, in the right conditions, severe algal blooms, are likely to occur as a consequence of heavy nutrient enrichment. In rivers, algal blooms may occur in sluggish stretches and backwaters but elsewhere enrichment is likely to manifest itself in turbid waters and weed growth, for example of Cladophora (blanket weed), a filamentous alga which is visually unattractive and interferes with fishing. In evidence to the Commission, the NRA said that considerable progress has been made in quantifying, for standing waters, the relationship between nutrient enrichment and effects such as increased plant growth. Predictive models of algal growth are well advanced. For flowing waters, however, the relationship is much less well understood.

6.8 British Waterways, in evidence to the Commission, stated that several stretches of its canal system had been designated class 3 under the NWC classification scheme although there was no obvious cause of pollution. The poor classification was apparently due to low levels of dissolved oxygen caused by excessive plant growth (see paragraph 6.5). British Waterways added that there were some stretches of waterway where weed growth was so heavy that it caused obstruction to

<table>
<thead>
<tr>
<th>Trophic category</th>
<th>Total phosphorus annual mean (mg/litre)</th>
<th>Chlorophyll a mean (mg/litre)</th>
<th>Transparency mean min (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-oligotrophic</td>
<td>&lt;0.004</td>
<td>&lt;0.001</td>
<td>&gt;12</td>
</tr>
<tr>
<td>Oligotrophic</td>
<td>&lt;0.010</td>
<td>&lt;0.0025</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Mesotrophic</td>
<td>0.010–0.035</td>
<td>0.0025–0.008</td>
<td>6–3</td>
</tr>
<tr>
<td>Eutrophic</td>
<td>0.035–0.100</td>
<td>0.008–0.025</td>
<td>3–1.5</td>
</tr>
<tr>
<td>Hypertrophic</td>
<td>&gt;0.100</td>
<td>&gt;0.025</td>
<td>&lt;1.5</td>
</tr>
</tbody>
</table>

Transparency is measured using a Secchi disc; figures apply only in lakes in which the water is not naturally coloured to a significant extent.

navigation and water flow. The resources required to control weed growth were considerable but the extent to which nutrient levels were responsible was not known. British Waterways also identified some canals designated as SSSIs where nutrient enrichment was threatening species diversity of aquatic plants. The Pocklington Canal in Yorkshire and the Chesterfield Canal were two examples; in both cases sewage works' effluents in feeder streams appeared to be contributing factors.

Nutrient levels in UK waters

6.9 The OECD has developed an internationally accepted set of criteria for classifying the trophic state of lakes and other standing waters (see table 6.1). It includes measures of total phosphorus, chlorophyll and transparency (see box 6.1). Some countries have used this classification scheme as the basis for comprehensive surveys. No such survey has been carried out in the UK, however, despite the environmental significance of eutrophication. We recommend in chapter 4 that such a survey should be carried out regularly. No internationally recognised system exists for classifying rivers on the basis of their trophic state and nutrient levels are not measured in the quinquennial river quality survey. There are therefore no comprehensive survey results available for nutrient levels in either rivers or standing waters in the UK.

**BOX 6.5 ORTHOPHOSPHATE LEVELS IN RIVERS IN ENGLAND AND WALES**

The histogram below shows that almost all monitoring sites in what are now the NRA's Severn-Trent, Anglian and Thames regions had annual mean levels of orthophosphate of over 0.15 mg/litre over the period 1975-1989. More than half were above 1.0 mg/litre. Nearly three-quarters of the sites in what are now the NRA's North-West, Yorkshire, Southern and Wessex regions were over 0.15 mg/litre and about one-third were over 0.6 mg/litre. Only one-quarter of sites in the area covered by NRA's Northumbrian, South-West and Welsh regions were over 0.15 mg/litre and virtually none were above 0.6 mg/litre. Results for Scotland (not shown) also reveal few sites above 0.15 mg/litre. These figures are not directly comparable with the criteria in table 6.1 since the table relates to standing waters while the HMS samples rivers. Levels of orthophosphate would generally be lower, by a factor of between 2 and 5, than levels of total phosphorus, referred to in the table.
Chapter 6

6.10 Some information is, however, available through the DOE’s Harmonised Monitoring Scheme (HMS) (see box 4.5 in chapter 4), which includes data on phosphate, nitrate and chlorophyll concentrations. Monitoring under this scheme takes place at a limited number of sites mainly at or near the tidal limit of major rivers but including also some more inland sites. Not all determinands in the scheme are monitored comprehensively: for example, only limited data are available on chlorophyll and total phosphorus. Orthophosphate concentrations are, however, well covered. The HMS data show that concentrations of phosphate at monitoring sites are in many cases orders of magnitude above both the natural ‘background’ level discussed in paragraph 6.3 above and the level at which lakes become eutrophic (see box 6.5). Data for virtually all monitoring points on rivers of any significance in the NRA’s Anglian, Thames and Severn-Trent regions show that these rivers are heavily enriched, as are a high proportion of the rivers in the NRA’s North-West, Yorkshire, Southern and Wessex regions. Lakes and reservoirs fed by these rivers would almost certainly be hypertrophic.

6.11 These data would appear to support the view expressed by the Natural Environment Research Council in evidence to the House of Lords Select Committee on the European Communities that ‘there is major eutrophication in the centre and south-east of England; most of the rivers are eutrophic’. This conclusion is borne out by what is known of the lakes and reservoirs in the regions. Many major rivers are used as water sources for public supply, the water being abstracted and stored in reservoirs before use. When lakes and reservoirs in England and Wales were monitored by the NRA in 1990, algal blooms were found at over 400 sites, indicating that the waters were likely to be hypertrophic. Some of those not exhibiting algal blooms may also have been hypertrophic, since blooms occur only when conditions are right. The case study of the Bedford Ouse (see appendix 5) confirms that reservoirs fed by that river suffer from such severe nutrient enrichment that special treatment processes have had to be installed and, in some instances, abstraction has had to be restricted.

The problem of nutrient enrichment

6.12 Although nutrient enrichment would appear to be widespread over large parts of the country, action to reduce inputs of nutrients to water has been taken in only a few selected places. The Government’s view, as expressed in the DOE’s evidence to us and more recently to the House of Lords Select Committee on the European Communities, has been that ‘eutrophication is a localised problem in the UK’ giving as examples the Norfolk Broads, Anglian and Thames reservoirs and Lough Neagh in Northern Ireland. This was based on the view that eutrophication is a problem if it ‘causes an increase in the growth of algae or other plants and shows a noticeable deleterious effect on the environment’. In their review of eutrophication in the UK, Lund and Moss took the view that:

‘there is no absolute level at which eutrophication presents a problem. Much depends on the perception and needs of the observer. Similarly, there is no single parameter which serves as a yardstick to assess the level of eutrophication at which a problem may be identified.’

Lund and Moss identified three groups that might have differing perspectives on the problem: the water industry, concerned with supplying potable water; conservation and environment organisations; and the wider public.

6.13 Lund and Moss pointed out that the water industry has considerable experience of coping with nutrient enrichment and has developed a range of techniques, some of which are described in box 6.9, for dealing with it. A report by WRC in 1977 identified problems for the water supply industry arising from eutrophication, essentially the need to treat water to remove suspended algae and compounds formed by reactions between chlorine and algal secretions. These secretions may also give rise to taste and odour problems and support growth in the public supply pipes of bacteria which, together with algal cells that also pass through the treatment process, can support communities of oligochaete worms and crustaceans in the pipes. Although these problems are being dealt with, treatment involves costs and does not always produce a final product which meets the expectations of the consumer (see, for example, appendix 5). Moreover, in some cases, treatment is ineffective. Lund and Moss quote three examples in the Anglian
region where water supply from reservoirs has had to cease either permanently or for part of each year because of problems associated with algal growth.

6.14 Lund and Moss note that conservation and environment organisations are mainly concerned about sites with known problems such as the Norfolk Broads, Windermere and Lough Neagh. Their report discusses a selection of such sites and in most cases recommends removal of phosphorus from sewage effluents affecting the sites. Lund and Moss further consider that progressively higher standards will be expected by the general public. Since many British water bodies have experienced some degree of enrichment from their original state, Lund and Moss argue that it will be difficult to define exactly what degree of restoration to seek. They consider that public demands in most upland areas could probably be met by phosphorus stripping at sewage works, together with more careful management of livestock slurries. In lowland areas, it may also be necessary to reduce the background loading from agriculture. We discuss this further in paragraph 6.22.

Quality objectives for enrichment

6.15 All three points of view – those of the water industry, conservation organisations and the wider public – are relevant in considering whether nutrient enrichment needs to be tackled. The system of water quality objectives should be capable of encompassing these points of view. Three developments of the system are required, however. First, quality objectives must be established for standing waters as well as for rivers, since it is in lakes and reservoirs that nutrient enrichment often presents the greatest difficulties. The NRA’s consultation paper on statutory quality objectives\(^10\) proposes such an extension and we recommend that this should be implemented. Secondly, the present range of quality objectives needs extending to take fuller account of the conservation and amenity issues raised by nutrient enrichment, both in standing and flowing waters. In particular, quality objectives are required which enable the desired ecological state of waters to be expressed. Proposals along these lines have also been made in the NRA’s consultation paper and we recommend that, in implementing them, the NRA should ensure that the quality objectives are defined in ways which enable the ecological impact of nutrient enrichment to receive attention. Thirdly, the water quality standards that are associated with quality objectives need to be extended to cover nutrient levels. In evidence to the Commission, Professor Moss pointed out that such standards would need to be more complex than those set for single-chemical pollutants such as heavy metals or pesticides. They need to take account of factors such as flow and temperature which also influence the trophic state of the water.

6.16 In setting quality objectives it will be necessary to consider to what extent it is desirable or practicable to restore waters to the trophic state that obtained prior to significant enrichment as a result of human activities. The NRA has initiated research to enable the present state of lakes to be compared with a baseline state reflecting the local environment of each lake earlier in this century, if not its pristine state. Determining baseline states for rivers poses more severe problems, and for reservoirs and other man-made lakes the concept may not be meaningful. The Broads Authority has established a policy of restoring the Broads to their condition at the turn of the century (see box 6.6). Inevitably such decisions involve value judgments which will require conservation and amenity issues to be balanced against cost and practicability. The proposed arrangements for setting statutory quality objectives (see chapter 4) will enable such judgments to be made throughout the country. Where the trophic state prior to significant enrichment resulting from human activities can be identified, we recommend that it should form the long term target for flowing and standing waters, though there may be many cases where it will not be practicable to achieve this target in the foreseeable future. In such cases, and also where such a baseline state cannot be identified, we recommend that quality objectives are set to secure conditions achieving an acceptable level of both species diversity and amenity. The existing widespread occurrence of eutrophic and hypertrophic lakes and reservoirs is not, in our view, desirable. Rivers that exhibit symptoms of excessive weed growth, siltation and other deleterious effects associated with enrichment are similarly undesirable. Equally, enrichment of nutrient-poor waters of conservation value should be avoided.
BOX 6.6 THE NORFOLK BROADS

The Broads are a collection of small shallow lakes, now between 0.7 metres and 1.5 metres deep, formed when medieval peat diggings flooded in the late fourteenth century. The catchment of the rivers feeding them covers about two-thirds of Norfolk and much of northern Suffolk (see figure 6.1). In the last 150 years the area covered by the Broads has been reduced by about one-half to some 600 hectares due to natural filling of the shallow lakes with dead vegetation and sediment.

The Broads area is a wetland of international importance for wildlife conservation, containing three national nature reserves and 24 SSSIs. It is increasingly popular with tourists, attracting more than 500,000 visitors each year, most of whom use the Broads for water recreation, particularly boating. The population of the catchment has also increased. Substantial areas of the fertile marshes surrounding the Broads have been drained for agricultural use.

Environmental change

The Broads Authority, in evidence to us, distinguished three phases in the development of the Broads (figure 6.2). Phase 1, lasting until the late nineteenth century in the Broads associated with the river Bure and as late as the 1960s in the Thurne Broads, was characterised by very clear water and a low density of open-water submerged plants. In phase 2, open-water plants began to be replaced by faster growing, taller water weeds and water lilies, and invertebrate, fish and waterfowl populations increased. By the mid 1960s, most broads had developed a phase 3 community, dominated by phytoplankton, with a loss of diversity of flora and fauna.

Typical phosphorus concentrations for these phases are as follows:

<table>
<thead>
<tr>
<th>Phase</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total P concentration (µg/litre)</td>
<td>&lt;60</td>
<td>100-125</td>
<td>&gt;125</td>
</tr>
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</table>

The loss of submerged plants and increase in numbers of powered boats has led to bank erosion by as much as 0.3 metres per year. Detritus from algal populations has also increased and annual sedimentation rates are in excess of one centimetre, compared with 1-2mm in past centuries. Heavy expenditure on dredging and piling is required to combat these problems.

Restoration

The initial aim was to reduce phosphorus concentrations. A target of 100 µg phosphorus/litre was set for part of the Broads, with the aim of re-establishing there a phase 2 community. Sewage effluent contributed about 80% of the phosphorus loading to this area. The then Anglian Water Authority took steps, since continued by Anglian Water, to reduce this. Effluent from one sewage treatment works was diverted to the sea and phosphorus stripping has been introduced at others. Despite reductions of 90% in phosphorus discharges to the area in question, concentrations in the Broads remained high (falling at Barton Broad, for example, from about 400 to 200 µg/litre) because of continued release of phosphorus from sediments. Dredging of up to one metre of sediment at Cockshoot Broad and elsewhere proved successful in reducing phosphorus concentrations to below 100 µg/litre but did not result in a return to a phase 2 community. Biomanipulation experiments at Cockshoot Broad and elsewhere have had some success. Water fleas consume phytoplankton but are preyed upon by small fish. Removing the breeding stock of fish leads to an increase in the water flea population, a decline in the abundance of phytoplankton and thus to clearer water. Submerged plants can then be reintroduced.

Sources: Broads Authority (1987)²; Moss et al. (1985)³.

Reductions in nutrients

6.17 Reversal of the effects of enrichment is likely to require removal of nutrients from effluents on a significant scale. In the Norfolk Broads a target of 0.1 mg/litre of phosphorus was set for the waters feeding some of the Broads (see box 6.6). Even if less demanding objectives are set for standing waters of lower conservation and amenity value, and for flowing waters, it seems
Figure 6.1 The Broads and their catchments including areas of environmental importance

Source: Broads Authority (1987).
inescapable that the nutrient levels required will be substantially below those currently existing in a significant proportion of the country. The Dutch government has set a target for rivers of 0.15 mg/litre of phosphorus as an annual average to be attained by the year 2000. We do not favour the adoption of a single national figure for the UK, preferring to approach the issue through water quality objectives related to the needs of each body of water. This will lead to requirements for phosphorus levels which will be more demanding than 0.15 mg/litre in some cases and possibly less demanding in others. In some circumstances, nutrients other than phosphorus, for example nitrogen, may also be important and standards for these will need to be set in order to achieve the water quality objectives.

6.18 In most cases, phosphorus concentrations in sewage works' effluents will have to be reduced in order to meet the objectives discussed above. The European Community directive on urban waste water treatment (91/271/EEC), adopted last year, sets phosphorus limits on sewage works discharging into 'sensitive areas'. For these purposes, sensitive areas are defined as waters where enrichment is causing or may cause 'an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.' Unless it can be demonstrated that removal of phosphorus will have no effect, the directive requires sewage works discharging into sensitive areas and serving populations of over 100,000 to achieve annual average phosphorus concentrations of 1 mg/litre in their effluents and those serving populations of between 10,000 and 100,000 to achieve 2 mg/litre. The directive requires the Government to designate sensitive areas by the end of 1993. The House of Lords Select Committee on the European Communities
pointed out in its report on the directive\textsuperscript{14} that the definition of sensitive areas was subjective and feared that 'its practical interpretation may give rise to considerable problems.' The Government has just published a consultation paper discussing the criteria for designating sensitive areas. This document arrived too late for us to consider it in detail but we recommend that the Government should take into account the views we set out in paragraph 6.16 that widespread eutrophication of lakes and reservoirs is undesirable, as are the deleterious effects associated with enrichment of rivers. Enrichment of nutrient-poor waters of conservation value is also to be avoided.

6.19 In some cases, to achieve the standards we describe in paragraph 6.17, it may be necessary to go beyond the requirements of the new EC directive by, for example, reducing phosphorus concentrations at works serving populations below 10,000 and by setting more stringent standards at larger works. About 90\% of sewage works in Britain serve populations of less than 5,000\textsuperscript{15}. Techniques for phosphorus stripping are described briefly in box 6.7. Chemical methods

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\textbf{BOX 6.7 PHOSPHORUS STRIPPING TECHNIQUES} \\
\hline
\textbf{Chemical treatment} \\
Conventional methods for the removal of phosphate from waste water at sewage treatment works are based on the precipitation of metal phosphates. Iron salts (iron chloride or iron sulphate), aluminium salts (aluminium sulphate) or lime compounds (calcium oxide or calcium hydroxide) are added to the waste water and a precipitate is formed which can be removed by sedimentation. The use of these precipitants also improves the quality of the final effluent by removing colloids and suspended solids, retaining other heavy metals in the sludge and reducing sludge odour and the COD of the effluent\textsuperscript{16}.

In Britain ferric sulphate is most frequently used as a precipitant and is generally added to the effluent after the secondary treatment stage (see figure 7.1 in chapter 7). About 90\% of total phosphorus can be removed in this way. The precipitate is either added to the sewage sludge or disposed of separately. Anglian Water estimated for us that the annual operating cost might typically be about £4 per person served by the works, with a range of £2-7, depending on local circumstances. Capital costs might range from £3 per person at large works to £30 or more at small works.

A process has been developed in the Netherlands, based on the crystallisation of calcium phosphate in a fluidised bed. It has the advantage of producing no sludge but rather a small quantity of water-free pellets of calcium phosphate that can be used as an industrial feedstock. Lime or caustic soda can be used for the crystallisation process. This technique is claimed to remove almost all the phosphate in the effluent but is complex and requires careful management to operate efficiently\textsuperscript{17}.

\textbf{Biological treatment} \\
Reed beds support the growth of large numbers of bacteria which break down organic substances in effluent percolating through the bed. Other constituents of the effluent may accumulate in the root zone or, as in the case of phosphate, be taken up by the plants. A report by the European Water Pollution Control Association in 1990 recorded the installation of some 500 reed beds for secondary treatment of sewage effluent in western Europe since 1984, of which 30 were in the UK. In general, beds can remove 20-30\% of total nitrogen, 30-40\% of total phosphorus and 80-90\% of BOD. They require quite large areas, about five square metres to treat the effluent from one person, and there have been problems engineering the flow of effluent in the beds. Most designs have relied on horizontal flows but vertical flow systems, which would improve flow and economise on space, are under development. There are alternative biological systems for large sewage works which rely on enhanced bacterial uptake of phosphate in activated sludge plants. Though employed in South Africa and the USA the technology is little used in Britain. Capital costs are high but operating costs are lower and smaller volumes of phosphate-enriched sludge are produced than with chemical treatment\textsuperscript{18}.

\textbf{Removal from diffuse sources} \\
Methods for phosphate removal from diffuse sources are less developed than those for point sources. Biological methods, for example the use of wetland buffers and corridors, are considered to offer more promise than chemical methods\textsuperscript{19}. The common reed and the water hyacinth are particularly efficient at taking up phosphate and other nutrients.
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Chapter 6

have been introduced at some sewage works in Britain, for example at Stalham, which we visited, in the Norfolk Broads catchment (see plate 17). Ferric sulphate is used there to precipitate the phosphate, which is then retained in the sewage sludge. There were initial problems with reliability of the process which appear to have been overcome. We understand, however, that chemical stripping processes are not at present practicable at unmanned sewage works. The operating cost of phosphorus stripping at Stalham sewage works was quoted to us as being equivalent to about £2 a year for every person served by the works. This is not a large sum but, at about 20–25% of the total running costs of the works, is not insignificant. Where it is necessary to man a previously unmanned works, the additional cost of providing the treatment would be correspondingly greater. The capital cost of installing chemical stripping will vary according to the size of the works. For a works serving a population of over 50,000 people, Anglian Water estimated for us that the capital cost might be as low as £3 per person. However, this could rise to £30 or more for works serving 5,000 people or fewer. Development of phosphate stripping techniques which are capable of wide application at reasonable cost is therefore to be encouraged; widespread installation of equipment may help to bring down costs. Methods which enable the phosphate which is removed from the effluent to be used beneficially, for example as fertiliser, would be welcome. We recommend that the Government work with the water industry and regulatory bodies to ensure that promising methods for phosphate removal are developed.

6.20 Other approaches to reducing phosphorus loads merit consideration. Between 30% and 50% of the phosphorus load at a typical sewage works is estimated to derive from detergents, the remainder being mainly contributed by human wastes. Eliminating the load from detergents could therefore make an important contribution to reductions in concentrations of phosphorus in surface waters where stripping at sewage works is not practicable. There may indeed be some parts of the country where removal of phosphorus from detergents, in conjunction with phosphorus stripping at a small number of large sewage works, would be sufficient to achieve target concentrations for phosphorus. This may apply in some upland areas with low population densities and waters which are naturally nutrient-poor. Several countries, for example Switzerland, Sweden, the Netherlands and Canada, have required or encouraged manufacturers to remove phosphate from detergents in order to reduce problems of nutrient enrichment in lakes. Although there has been no Government encouragement to remove phosphate from detergents in Britain, phosphate substitutes are taking an increasing share of the market. Many of the recently introduced compact powders are based on formulations developed for the continental European market and use mainly zeolites in preference to phosphate (see box 6.8). Liquid detergents, which have recently taken a significant share of the UK market, are also phosphate-free. A study for the DOE estimated that about a fifth of detergent phosphate use in the UK had been replaced by alternatives in 1990; the figure may have risen to about a third in 1991.

6.21 Although, as we conclude above, the present level of phosphorus entering freshwaters is undesirable, phosphorus substitutes should not be widely introduced until their environmental effects have been fully assessed and shown to be acceptable. Concerns have been raised about some of the potential substitutes, particularly NTA and EDTA (see box 6.8). We therefore asked Environmental Resources Limited to review the environmental effects of these and other components of cleaning products. Their review indicates that there are strong arguments against the use of NTA and EDTA but there are fewer concerns about zeolites and PCA. The Government has also recently reviewed the environmental impact of these substances and has, as a result, strengthened existing voluntary agreements with industry on the use of NTA and EDTA in detergents. We welcome this and also the establishment of arrangements to keep under review information on the use and environmental effects of detergents. The EC Commission has, meanwhile, embarked on a study of phosphate and its substitutes in detergents, covering their production, environmental effects and the effectiveness of alternative formulations in cleaning, and comparing their economic costs. We place considerable emphasis on the need for careful evaluation of phosphate substitutes. In order to perform effectively in detergents these substances are likely to have an affinity for metal ions. If the substances were persistent in the environment, their use could lead to heavy metals being mobilised, with potentially adverse consequences which could far outweigh the benefits from removal of phosphate. We recommend, therefore, that caution should be exercised in replacing phosphate in detergents until the environmental effects
have been fully evaluated and found to be acceptable. There are, however, other ways of reducing phosphate use in detergents which deserve investigation. For example, the quantity of detergent required for washing in soft water is less than in hard water. We recommend that the Government consider with detergent and washing machine manufacturers whether it could be made easier for consumers to take advantage of this fact to reduce their use of phosphate. We note, for example, a report that one major supermarket chain is now marketing a phosphate-free washing powder, with zeolite softener and sodium percarbonate bleach sold separately so that the consumer need only add the amounts required for each wash\textsuperscript{22}. Similar approaches may be possible with phosphate-based formulations.

**BOX 6.8 PHOSPHATES AND WASHING POWDERS**

Washing powders rely for their cleaning effect on surface active agents or detergents. These are long chain organic molecules, hydrophilic (‘water loving’) at one end and hydrophobic (‘water hating’) at the other end. The hydrophobic end of the molecule associates with grease and the hydrophilic end associates with water, facilitating the removal of dirt from fabrics and its suspension in water. Commercial washing powders also contain substances known as builders. These improve the performance of the product by:

- removing calcium and magnesium which otherwise greatly reduce the efficiency of the detergent;
- maintaining an alkaline pH, necessary for the surface active agents to function correctly;
- keeping soil particles suspended;
- stabilising the physical properties of the washing powder.

The more effective the builder is in these respects, the better the wash and the smaller the amount of detergent needed. The commonest substance used as a builder in washing powders sold in Britain is sodium tripolyphosphate (STPP) which constitutes some 20–40\% by weight of the powder. Phosphate builders are estimated to contribute 30–50\% of the phosphate in sewage works' effluents in Britain. Although phosphate builders are effective and non-toxic, concern over eutrophication has led to a search for replacement builders. These include:

- **Zeolites** – non-toxic crystalline alumino-silicates with pores that give the molecules a large internal surface area, binding calcium and, less effectively, magnesium, but removing these ions from solution more slowly than phosphates. Higher concentrations of zeolites must therefore be used. Zeolites may absorb and carry over metals into the receiving waters and must be removed during water treatment. Since zeolites are insoluble and inert their use increases the volume of sludge and reduces its calorific value. Zeolites cannot buffer alkalinity and lack soil dispersion properties. They must therefore be used in conjunction with another builder, typically a poly-carboxylic acid.

- **Polycarboxylic acids (PCA)** – have been used for some years in small quantities as anti-redeposition agents. They do not biodegrade and their effects on health and the environment have still to be investigated fully.

- **Citric and tartaric acids** – rapidly degraded in the environment and effective sequestering agents for calcium and magnesium. Their cost prohibits widespread use at present.

- **EDTA (ethylene di-amino tetra acetate)** – not widely used in washing powders because of its high cost and the hazards which arise from its ability to mobilise metals in the environment. EDTA is banned in some countries.

- **NTA (nitriolriacetic acid)** – a water soluble organic acid that sequesters calcium and magnesium. There are concerns over its carcinogenicity and toxicity and its use has been banned in New York State and restricted in Switzerland, Germany and Italy.

Over half a million tonnes of washing powders and liquids are sold annually in Britain. There is a trend towards reduction in the use of STPP. Phosphate free products have been introduced and the new concentrated washing powders are nearly all phosphate free. STPP substitution is much more common elsewhere in Europe.
6.22 Reduction of phosphate concentrations in sewage works' effluents, whether by phosphorus stripping or by reduction of use in detergents, may not always be sufficient to achieve adequate reductions in nutrient levels in receiving waters. Other nutrients, in particular nitrate, may need to be controlled and reductions in phosphorus inputs from sources other than sewage works may be needed. A study for the EC Commission\textsuperscript{23}, quoted by Lund and Moss, estimated that, across the country, over one-third of phosphate input to surface waters came from agricultural sources. In evidence to us, the NCC estimated that, even in areas of high population, agriculture contributed about 20% of the phosphate input to freshwaters. Agriculture is also the main source of nitrate in freshwaters, although important contributions also come from sewage works' effluents. Steps to reduce pollution of rivers by animal slurries, as discussed in chapter 7, would help to reduce phosphorus and nitrogen inputs from this source. A recently published report by the NRA\textsuperscript{24} on the influence of agriculture on water quality in England and Wales contains a number of other recommendations which would be relevant to the control of nutrient inputs into waters. These include a review of discharge consents for farm effluents and the development of risk assessment procedures for catchments where farming poses a threat to water quality. The NRA's report also states that research and practical experience in other countries has shown that buffer zones alongside watercourses can have a beneficial effect on water quality. Nutrients, as well as silt and other substances, are trapped, broken down or assimilated in biological material so that water contamination is reduced. The NRA's report recommends practical investigations to test the value of buffer zones. We consider that these recommendations merit support.

6.23 Reduction of inputs of nutrients may not, by itself, always be sufficient to enable enriched waters to recover, particularly lakes and reservoirs where the water has a high residence time.

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\textbf{BOX 6.9 RESERVOIR MANAGEMENT TO REDUCE THE IMPACT OF EUTROPHICATION} \\
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Chemical treatment is sometimes used to reduce nutrient levels in reservoirs. For example, iron sulphate has been used to reduce the phosphate input to the Foxcote reservoir in East Anglia. The treated inflow was discharged into a shallow bay where the iron flocculate and the phosphate could be recovered by dredging. \\

Nutrient levels may, in theory, be decreased by deliberately encouraging the growth of plants and animals and harvesting them, or by controlling food webs, for example by removing fish, so that organisms, such as zooplankton, that consume algae, are favoured. Pre-reservoirs have been widely used for reducing the input of nutrients into reservoirs and lakes by retaining the inflow water for a few days. Algal blooms are encouraged to develop in the pre-reservoirs to consume the nutrients available and as the algae die they can be removed, taking with them some of the phosphorus. Retention periods of some 15 days can reduce phosphorus levels by 60% but a combination of ponds can remove 90%. This technique has a large land requirement, however, and is much less efficient in winter than in summer. Fish are also useful for removing algae and plants. If the fish are then taken from the waterbody a reduction of about 2 g of nitrogen and 0.2 g of phosphorus per 100 g of wet fish flesh, depending on the fish species and lake fertility, can be achieved. Not all the algae in the lake can be controlled in this manner but in the UK roach and rudd have been useful direct consumers of algae. Nitrate in lake waters can be removed by being consumed by algae or by denitrification by bacteria in the lower, anoxic levels of the lake. In the hypertrophic Lake Hartsbeesport in South Africa some 50% of the combined nitrogen load is removed in this manner, reducing the N:P ratio from 10:1 to 5:1, that is from phosphorus limited to nitrogen limited. This shift favours the troublesome \textit{Microcystis} which is dominant in the lake; attempts are being made to limit the input of phosphorus from effluents to promote algal species more palatable to the lake's zooplankton. \\

It is also possible to control algae using chemicals or by physical control of the waterbody. Copper sulphate and other algicides and herbicides have been used in reservoirs, though the selection of the herbicide, especially with regard to the toxicity of breakdown products, is critical; for example, copper sulphate can damage fish stocks. In nutrient rich reservoirs, water circulation has been used to inhibit algal blooms by preventing the algae from remaining for long periods at the surface of the water. \\
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High phosphate levels in sediments will provide a source of phosphate and enrichment of the water will continue. Dredging has been used to remove nutrient-rich sediment in the Norfolk Broads. Elsewhere, lake bottoms have been sealed, using polythene or layers of sand, in order to prevent the exchange of phosphorus between sediment and the water column. There has been work on the use of fly-ash or phosphorus-absorbing aluminium gels to replace sand used for this purpose. Unfortunately these agents can encourage the formation of anaerobic bottom sediments. Other methods to manage eutrophic standing waters are described in box 6.9. In some cases, as in the Broads, biomanipulation may also be required (see box 6.6). These techniques can be extremely costly. In evidence to us both the NCC and the Broads Authority commented on the difficulty of meeting such costs within their budgets. The 'polluter pays' principle would suggest that the cost of remedial works and, indeed, the cost of reducing new inputs by phosphate stripping and other means, should fall on those who are responsible for introducing phosphorus into the environment. The charging scheme that we propose in chapter 8 would help to achieve this by imposing a charge on those discharging phosphate, the income from which could be used for works to reduce enrichment problems. There may also be scope for other economic instruments to reduce inputs of phosphorus and raise funds for remedying its adverse effects.

6.24 The variety of sources of nutrients, the range of their effects and the problems of remedying historic burdens in sediments mean that no single solution to nutrient enrichment is likely to apply. We therefore endorse the conclusion of the House of Lords Select Committee25 that 'integrated strategies . . . be established on a site by site basis' and we so recommend. The development of such strategies will require consideration of the full range of nutrient inputs, their relative contributions to problems of enrichment and the availability of control measures. The NRA pointed out in its evidence that eutrophication was relevant to all its functional activities, including control of discharges, the use of water protection zones and the management of fisheries, conservation, recreation, navigation, water resources and flood defence. Catchment management plans, which we describe in chapter 9, offer a framework for bringing all these aspects together to develop integrated strategies. We are therefore pleased to note that the NRA, in evidence to the Commission, confirmed that it saw catchment management plans as the best way of addressing problems of nutrient enrichment.

ACIDIFICATION

Introduction

6.25 Peat bogs, organic soils and some freshwaters are acidic as a result of naturally-occurring processes (see paragraph 6.33). However, in many places natural acidity has been enhanced by the deposition of acid gases and particles emitted by industrial processes and vehicles, and by changes in land use. Acid deposition, often in the form of acid rain, has damaged soils, trees, natural vegetation, the aquatic environment and buildings in many countries.

6.26 Acid emissions may travel long distances before they are deposited and can therefore contribute to acidification in other countries as well as in the country of origin. The UK is a net exporter of sulphur dioxide (SO₂), one of the main acidic airborne pollutants, and exports about 70% of the total it produces. Over half falls in the sea, but the remainder is deposited in other countries, principally in Scandinavia26. In 1987, 505,000 tonnes of anthropogenic sulphur were deposited on the UK. Of this, about two-thirds came from UK sources27. Some of the most acidic deposition episodes in the UK, however, are associated with European emissions carried by easterly winds28. The transboundary aspect of acidification is reflected in the concern expressed in the international community over the effects of acid deposition and in the many initiatives developed internationally to address the problem. Many studies have been carried out to establish the extent and effects of acid deposition in the UK. Comprehensive reports have been produced by, amongst others, the UK Review Groups on Acid Waters29 and Acid Rain30 (1989 and 1990, respectively) and, for Scotland (also Norway and Sweden), under the auspices of the Royal Society's Surface Waters Acidification Project (SWAP)31.
Evidence of increased rates of acidification of freshwaters

6.27 Studies of communities of diatoms (single-celled algae) in sediments, which reflect past changes in the pH of waterbodies (see box 6.10), have shown that most surface waters which are currently suffering from acidification began to acidify after 1830; they now have pH levels of between 4.5 and 5.5 (neutral water has a pH of about 7.0). An acceleration in pH change occurred at many of the sites studied during the period 1930–1970; in Wales a number of sites became acidified for the first time after 1940.

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<thead>
<tr>
<th>BOX 6.10</th>
<th>DIATOMS AS INDICATORS OF pH</th>
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<tr>
<td>Diatoms are single-celled algae which occur in lakes in great abundance and diversity. They rapidly multiply in the growing season. When they die, they accumulate in the sediment. They possess silica-containing cell walls which are preserved in the sediment and form a record of past lake populations. Each species of diatom grows best over a specific limited pH range and so the range of species found in any one lake is strongly influenced by the chemistry of the lake water. The range of diatoms in sediments therefore indirectly records changes in the past pH regime of the lake.</td>
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</table>

Current degree of acidity of UK freshwaters

6.28 In the UK, waters of moderately severe acidity are currently found in central and south-west Scotland, the Pennines, south-west Cumbria and central and north Wales, resulting, in some cases, in depletion of fish stocks. Two of the worst affected areas are Galloway in south-west Scotland and the uplands of central and north Wales. In these regions, the combination of base-poor soils and rocks (see box 6.11) and high loads of wet acid deposition have acidified waters to below pH 5.0 and these are now virtually devoid of fish. Acid deposition is very high in these areas and appears to be the major causal factor. In addition, afforestation has exacerbated freshwater acidity in central and south-west Scotland, south-west Cumbria, the Pennines and central and north Wales (see paragraph 6.40).

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<tr>
<th>BOX 6.11</th>
<th>BUFFERING CAPACITY OF SOILS</th>
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<tr>
<td>Base-rich soils, such as chalk and limestone, contain a high proportion of cations which are derived from weathering of the bedrock. These cations neutralise acidity. In the event of heavy rain the cations are washed through the soil, leaving the soil temporarily acidic. It follows that areas of heavy rainfall, such as upland regions of the western seaboard of the UK, where bedrock, especially granite and slate, weathers slowly and is base-poor, will be the most susceptible to acidification. These areas include south-west Scotland, central Wales, Cumbria and the Pennines.</td>
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</tbody>
</table>

6.29 Evidence submitted to us by the Clyde River Purification Board reported recent acidification of the upper Doon and Stinchar catchments in Strathclyde accompanied by a loss or deterioration of fisheries in the Doon catchment (trout in Loch Enoch, charr in Loch Doon) and an impoverishment of invertebrate communities. The Scottish River Purification Boards Association reported a severe decline in fisheries, attributed to acidification, in the Luce, Cree, Fleet and Dee catchments in south-west Scotland, the Isle of Arran, the east side of the Mull of Kintyre, the area around Dunoon, and the part of Wester Ross that is centred on Gairloch and Torridon. The former Welsh Water Authority informed us that acidification has also been identified as a major problem in the Upper Tywi catchment in Dyfed, Wales, where there has been a steady decline in salmonid fisheries during the past 15 years. Many lakes in afforested catchments in central Wales have also shown a deterioration or complete loss of trout in recent years, pointing to land use as a factor influencing acidification (see paragraph 6.40).
6.30 The DOE reported, in evidence to us, that diatom and chemical records show that there has been partial recovery of freshwaters at some Scottish sites, such as Galloway, since 1975, and more recently in the river Esk in Cumbria. These changes correspond to the reduction in SO₂ emissions in the UK since about 1970. However, no reduction in acidification is apparent at Welsh sites. Models predict that a reduction in deposition of SO₂ of about 50% from 1984 levels would prevent further biological change in moorland surface waters in Wales. The UK Acid Waters Review Group (UKAWRG) reported that under these conditions, Scottish waters would improve. Models also predict that a reduction of 90% from 1984 acid deposition levels would be required to return most UK surface waters to near-pristine condition.

6.31 On the recommendation of the UKAWRG, the Government has established a network of monitoring sites in the UK in recent years to permit assessment of trends in surface water acidity. The monitoring programme began in 1988 at 20 sites, 10 of which are lakes and 10 streams, and was expanded in 1990 by the addition of two further sites in Northern Ireland. The sites are located in those parts of the country which are most susceptible to acidification, namely the Scottish Highlands, central Scotland, Galloway, Cumbria, the southern Pennines, Ashdown Forest (south-east England), south-west England, the Welsh Uplands, and the Antrim plateau and Mourne Mountains in Northern Ireland.

6.32 In 1984, the British Geological Survey (BGS) undertook a study for the DOE into the susceptibility of UK groundwaters to acid rain, which was the first of its kind in the country. The subsequent report revealed that most UK aquifers used to supply drinking water are well buffered and therefore not vulnerable to acidification. This is not the case for certain shallow groundwaters, such as those in north-west England and in Shropshire, nor for many small private water supplies obtaining water from shallow wells and springs in areas with a low calcareous content in the aquifer, such as those in Wales and northern and western Britain. There is a general tendency for acidification to increase the concentrations of aluminium, zinc, copper and nickel in groundwaters which may result in increased levels in water supplies. We therefore recommend that the Government ensure the effects of acidification on unbuffered groundwaters are assessed.

Sources

6.33 Both natural and anthropogenic sources contribute to the acidification of soils and freshwaters. Unpolluted rain water is moderately acidic (about pH 5.6), largely because it has absorbed natural acid gases such as carbon dioxide and sulphur dioxide from the air. This natural SO₂ comes from the atmospheric oxidation of dimethyl sulphide, a gas produced by certain plankton in the sea which are particularly active in the spring and summer. Minor natural sources of acidity are SO₂ from volcanoes and hydrogen sulphide from the anaerobic decay of organic sediments. In the soil, acidity comes mainly from carbon dioxide and organic acids produced by microbial degradation of soil organic matter. Iron-rich soils and rocks can also contribute to the acidity of waterbodies when iron pyrites (FeS₂) is oxidised to sulphuric acid by bacteria. Atmospheric acid inputs from natural sources make a smaller contribution to the acidification of soils and freshwaters in the UK than those from anthropogenic sources. However, in western coastal areas of the UK remote from man-made sources, up to 60% of the sulphate in rainfall may come from the natural marine source.

6.34 The main anthropogenic acid gases are SO₂ and nitrogen oxides (NOₓ). Hydrogen chloride makes a small contribution to acidification. There is growing recognition that ammonia alters the site of local acid deposition and contributes to soil and water acidification, despite its ability to neutralise acid gases in the atmosphere (see box 6.12).

6.35 Table 6.2 lists the main sources of acid pollutants in the UK. The major anthropogenic source of SO₂ is the combustion, in power stations and industrial plants, of fossil fuels, such as coal and oil, which contain sulphur. Total emissions of SO₂ in the UK fell by about 25% between
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BOX 6.12 THE CONTRASTING ROLES OF AMMONIA IN REDUCING AND ENHANCING ACIDITY

Ammonia is the most prevalent alkaline gas in the atmosphere and arises mainly from livestock wastes. Its complex reactions with acid pollutants in the atmosphere can significantly alter the amount and site of deposition of these pollutants. Ammonia appears to enhance the uptake and oxidation of SO₂ from the air into clouds, thereby inducing correspondingly high concentrations of sulphur in rain. Ammonia also neutralises sulphuric and nitric acids in rain, by reacting with them to form the ammonium salts, ammonium sulphate and ammonium nitrate. It is thought that these two processes work together in such a way that ammonia rapidly transferred from the air into acid cloud droplets, neutralises the acidity sufficiently to allow further uptake and oxidation of SO₂. The MARTA (Modelling Atmospheric Reactions and Transport of Ammonia) model has been developed at Imperial College in London to analyse the interaction of ammonia with acid pollutants, and the contribution of ammonium ions to acid deposition.

Although there is insufficient ammonia in the atmosphere to neutralise completely all the acid pollutants present, ammonia emissions, particularly from livestock, alter the properties of atmospheric aerosols and decrease the overall acidity of rainfall. However, after deposition in water or on soil, ammonium compounds may be either oxidised to nitrate or taken up by plants or both. Both processes produce hydrogen ions and hence, despite the alkaline properties of ammonia, can contribute significant additional acidification.

1980 and 1989. Oxides of nitrogen are formed during a very wide range of combustion processes; motor vehicles and power stations are the two most important sources in developed countries. NOx emissions rose by about 10% between 1980 and 1989, mainly due to an increase in emissions from motor vehicles of nearly 50%. Gaseous ammonia emissions arise almost entirely from livestock wastes although a small proportion (possibly 5%) arise from fertiliser applications.

<table>
<thead>
<tr>
<th>Table 6.2</th>
<th>The main sources of acid emissions in the UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated emissions (thousand tonnes)</td>
</tr>
<tr>
<td></td>
<td>1980</td>
</tr>
<tr>
<td><strong>SO₂</strong></td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>Power stations</td>
<td>3007</td>
</tr>
<tr>
<td>Industrial plants a</td>
<td>1089</td>
</tr>
<tr>
<td>Others b</td>
<td>798</td>
</tr>
<tr>
<td>Total emissions</td>
<td>4894</td>
</tr>
<tr>
<td><strong>NOx</strong></td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>Power stations</td>
<td>880</td>
</tr>
<tr>
<td>Industrial plants a</td>
<td>328</td>
</tr>
<tr>
<td>Road transport</td>
<td>884</td>
</tr>
<tr>
<td>Others b</td>
<td>350</td>
</tr>
<tr>
<td>Total emissions</td>
<td>2442</td>
</tr>
</tbody>
</table>

a Excludes power stations, refineries and agriculture.
b Includes domestic, commercial/public service, refineries, agriculture, railways, road transport (except in the case of NOx emissions), civil aircraft and shipping.

Source: Department of the Environment (1991)38.
Between 1950 and 1980, ammonia emissions increased by about 50% in the UK and over Europe as a whole\textsuperscript{39}. The most recent published data for hydrogen chloride emissions in the UK (1983) show that about 90% result from the burning of coal with a high chloride content and about 6% arise from the incineration of chlorine-containing refuse\textsuperscript{40}.

6.36 Some airborne acid emissions, particularly hydrogen chloride, are deposited close to their sources. More typically, gases are dispersed from their sources; they may travel hundreds of kilometres. During dispersal they may undergo complicated chemical conversions before being washed out of the atmosphere and eventually precipitated in rain or snow. Sulphuric acid is formed in the atmosphere from SO$_2$; more slowly than nitric acid is formed from NO$_2$. SO$_2$ can therefore be carried further from the emission source before it is deposited\textsuperscript{41}. Over most of the UK, wet deposition predominates owing to the high levels of precipitation, especially in many northern and western areas, where over 80% of total sulphur deposition is wet deposited. Only in parts of central and southern England is dry deposition the major component\textsuperscript{42}. Occult deposition of acid pollutants also contributes to acidification (see paragraph 6.40).

**Effects of acidification on freshwater quality**

6.37 The UKAWRG considered that acidification of natural waters is unlikely to affect public health through water supplies. However, as a waterbody becomes more acidic some biota are affected directly by the changing pH, while others suffer from consequent increases in toxic metals, particularly aluminium (see box 6.13). In acidic wetland habitats, plant communities become dominated by acid-tolerant plants such as *Sphagnum* mosses or liverworts. Macro-invertebrates do not all react in the same way to acidification; less acid-tolerant species, including crustacea and mayfly larvae, are scarce in acid waters, despite widespread occurrence elsewhere. The common frog has a reduced breeding success in south-west Scotland, where waters are extensively acidified, and is generally not found in acidified waters. The natterjack toad has been lost from acidified inland breeding pools.

6.38 At a pH below 4.5, acidity directly affects fish, particularly salmon and trout which are less tolerant than coarse fish. Acidity affects growth and the survival of eggs and fry. Fish kills have been reported after episodes of high acidity which are often accompanied by high concentrations of dissolved aluminium and usually occur when snow melts or when rain follows a long dry spell. The absence of fish leads to a decline in the numbers of piscivorous vertebrates, such as ospreys, divers and otters. Otters are absent from the acidic headwaters of the Severn, but present along adjacent streams which are not acidic. This may reflect reduced fish abundance in acid waters. Alternatively, the acidic waters may be in outlying areas which have not been colonised by the otters. The numbers of dippers have declined along acid streams in Scotland and Wales, probably as a result of reduced numbers of macro-invertebrate prey near the dippers’ breeding sites.
Chapter 6

Afforestation

6.39 Many upland catchments in the UK, particularly in the north and west, are planted with conifers of varying age. Coniferous forest currently accounts for about 7% of the land area in Great Britain as a whole (8% in Wales, 12% in Scotland and 3% in England)43.

6.40 The run-off from some conifer forests is more acidic and contains higher levels of aluminium, sulphate and nitrate ions than that from other types of vegetation. This is because conifer forests are efficient scavengers of acid pollutants from the air, mist and clouds, particularly when the tree canopy is almost complete, 10 to 15 years after planting44. The deposition of acid pollutants captured in this way is known as occult deposition. Increases in the acidity of soils and waters following afforestation occur most commonly in upland areas where the deposition of acid pollutants is high and where the soils have a limited buffering capacity because they overlie rock, such as granite or slate, which is deficient in base cations (see box 6.11). Under these conditions, forests can significantly increase local deposition of sulphur and nitrogen. Such areas include central and south-west Scotland, south-west Cumbria, the Pennines and central and north Wales. The UKAWRG considered that the effect of planting conifers on an upland moorland catchment with poor buffering capacity and high acid deposition, could be equivalent to a 30% increase in acid deposition. The former Welsh Water Authority informed us that it had developed guidelines on forestry planting, seeking to restrict planting to 10% of the land area in catchments with low water hardness, rising to 70% in areas with high water hardness since such areas are better able to neutralise acidity.

6.41 The Forestry Commission acknowledges the effects of afforestation on surface waters in regions with low buffering capability. It has published detailed guidance45 on techniques of forest establishment and management intended to ensure, as far as practicable, that water draining from forests is of a satisfactory standard. In 1991 the guidance was revised to include reference to the critical loads approach (see paragraph 6.46) to protect sensitive waters from acidification. The Forestry Commission now advises that, if afforestation is to be undertaken in areas where critical loads are exceeded, or where planting could cause them to be exceeded, then a precautionary application of powdered limestone should be made prior to canopy closure. The Forestry Commission advises that this is likely to be necessary only on catchments at altitudes above about 300 metres (400 metres in the drier east of the country) and where forest cover exceeds about 10% of the catchment above this altitude. The guidance warns against applying limestone where adverse ecological impacts would result (see also paragraph 6.45). Applications for grant aid for afforestation are subjected to scrutiny by the Forestry Commission and to consultation with local authorities and environmental agencies. The Forestry Commission may require an application to be subject to an environmental assessment when it judges that a proposed new planting may have a significant effect on the environment because of its size, nature or location. The Commission requires applications to conform to its guidelines on forests and water and may refuse a grant where the expected effects are severe and it is not possible to reduce them to acceptable levels46.

6.42 Rural regional councils in Scotland have prepared, or are in the process of preparing, indicative forestry strategies, which will indicate to prospective planters when land may be sensitive, inter alia, in terms of water quality. DOE and the Welsh Office are currently consulting over proposals to extend indicative forestry strategies to England and Wales. The strategies would be prepared by county councils and national park authorities where they considered it to be helpful.

6.43 We consider that the Forestry Commission’s revised guidelines and the requirements for environmental assessment provide a firm basis for reducing adverse effects of forestry on water quality. The incorporation of appropriate policies in indicative forestry strategies could bring further improvements. We consider, however, that the Forestry Commission’s guidelines appear to place too much reliance on liming to mitigate the effects of acidification. For the reasons discussed in paragraph 6.45, we view liming as a short-term ameliorative measure, not as an alternative to prudent land use practices. We consider that it may be necessary to restrict planting in some sensitive catchments and we recommend that the Forestry Commission incorporate advice to that effect within its guidelines. We also recommend that water regulatory authorities,
in developing their catchment management plans (see chapter 9), should incorporate appropriate policies for afforestation on sensitive catchments including guidance on locations where it might be necessary to restrict planting. We further recommend that local authorities and national park authorities reflect such policies in their indicative forestry strategies.

**Liming**

6.44 Liming (the application of a calcareous mineral such as powdered limestone or chalk) is the usual means of counteracting soil acidity for agricultural purposes, especially in upland areas. However, agricultural liming of upland soils has declined in the last two decades since Government subsidies were removed; this might have enhanced acidification. Liming of surface waters is carried out with the aim of keeping the pH above about 5.5 (see box 6.13) and increasing the calcium content, while reducing the concentrations of dissolved heavy metals and aluminium. The quantities of limestone or chalk required depend on the acidity and natural buffering capacity of the water as well as on the method of application and the flow rate of streams and rivers or the turnover time of lakes.

6.45 Several pilot schemes in the UK have shown that, by increasing the pH and calcium content and reducing the solubility of aluminium and other heavy metals, liming the water directly serves to render the water acceptable again to the most sensitive species, including crayfish and brown trout. However, it requires repeated dosing, especially to fast flowing waters, to remain effective. If liming is discontinued and the water re-acidifies, some heavy metals, such as cadmium, which had precipitated out of solution and accumulated in the sediment, may be released and poison the aquatic biota. In practice, this is unlikely to be a problem except in flowing waters; there has been no evidence of re-acidification of lakes following the cessation of liming. Widespread liming of catchments could damage animal and plant communities and may encourage the development of a different ecosystem to that present before acidification. Furthermore, liming of catchments is expensive. For these reasons, the NRA does not advocate blanket liming, but rather the identification of sites, such as those of importance as fisheries, which would be particularly suited to, and derive the maximum benefit from, liming. We consider that liming should only be regarded as a short-term, ameliorative measure and should be used in conjunction with, rather than as an alternative to, efforts to reduce acid emissions and to change land use practices which exacerbate the impact of acid deposition. We support the NRA’s view that liming should be restricted to suitable sites which will derive the maximum benefit. We recommend that liming programmes should incorporate arrangements to monitor their impact.

**Critical loads**

6.46 In recognition of the long range transport of acid emissions and the effects of their deposition, many Governments have agreed to implement reductions in acid emissions. The earliest planned reductions were based on uniform percentage cuts. These can, however, impose unnecessarily high costs whilst failing to achieve their environmental objectives. The ‘critical loads’ concept has been developed within the UN-ECE as a means of quantifying the sensitivity of ecosystems to pollutants. It enables an objective baseline to be established as a foundation for negotiated emission reductions. The Government is giving support to this approach in discussions within the UN-ECE. A ‘critical load’ is defined as the maximum load that a given ecosystem is known to be able to tolerate without suffering adverse effects. In the case of surface waters, the critical load is set to ensure maintenance of water quality suitable for the survival of salmonid fish and other freshwater biota which are particularly sensitive to acidic conditions. Critical load calculations must take account of soil, geology and land use characteristics of a given area, as these factors can influence the susceptibility of freshwater ecosystems to acid deposition. Thus the critical load differs from place to place. The results are presented in the form of maps. The critical loads approach has been adopted as the basis of the reductions required under the second stage of the UN-ECE Protocol on nitrogen oxide emissions from 1994. A new agreement to reduce SO$_2$ emissions, under negotiation within the UN-ECE, is also likely to make use of the critical loads concept. The existing UN-ECE agreement requires that SO$_2$ emissions are reduced by 30% from the 1980 baseline, by 1993. Achievement of the critical loads in the UK will ensure
that UK acid emissions do not contribute to the exceedance of the critical loads elsewhere in Europe.

6.47 A provisional map showing the critical loads for acidity for standing freshwaters in Great Britain has been prepared for the DOE by the UK Critical Loads Advisory Group (CLAG) (see plate 16(a)). It shows that the freshwaters most susceptible to acidification by sulphur deposition in Great Britain are in north-west Scotland, mid Wales, Cumbria and the Pennines where the critical load is less than 0.2 kilogram equivalent of hydrogen ions per hectare per year. Sulphur deposition exceeds this load over 8% of Great Britain (see plate 16(b)).

6.48 In parallel with the development of critical loads maps, models have been developed which relate acid emissions to the acidification of water and soils. Modelling pollutant emissions and the resulting deposition loads can show where, and how much, emission control is required to reduce deposition below the critical load. By incorporating the estimated costs of emission controls into the models, the most cost-effective strategies for abating emissions can be calculated.

6.49 The critical load of a pollutant for a sensitive ecosystem may, even using the most advanced techniques to reduce emissions, be incapable of achievement without high cost. In such cases, the critical loads concept enables economic or other effects of a reduction programme to be brought explicitly into the process of negotiation. As a step towards critical loads, these factors can be used to develop target loads which contracting parties use as the basis for an agreement.

Reductions in emissions

6.50 International agreements and EC directives currently in force to limit and reduce emissions of SO$_2$ and NO$_x$, the main acid airborne pollutants, and the measures being taken to meet these requirements, are described in box 6.14. Plate 16(c) illustrates the Government's target for the reduction of sulphur deposition by 2005 in Great Britain, based on the EC Directive on Large Combustion Plants (LCP) (88/609/EEC) and on Part I of the Environmental Protection Act 1990. The DOE says that, on this timescale, it will not be practicable either in the UK or in most other UN-ECE countries for sulphur deposition to be reduced to non-damaging levels in all places. Even though deposition will have been reduced substantially, the more sensitive freshwaters, which account for 7% of the surface area of Great Britain, will still be sustaining damage.

6.51 The UK has been criticised for a dilatory approach to the reduction of acid emissions. It did not ratify the SO$_2$ Protocol (the "30% club") because the base year (1980) against which reductions would be assessed was less favourable than the Government considered reasonable. The total reduction in SO$_2$ emissions required of the UK under the LCP Directive (see box 6.14) is lower (at 60% of 1980 emissions) than for other member states such as Belgium, France, Germany and the Netherlands (70%). While the UK has been resisting a widespread Flue Gas Desulphurisation (FGD) programme, the former Federal Republic of Germany has retrofitted such equipment to virtually its entire generating plant. The UK commitment to retrofit 12,000 megawatts of coal-fired generating capacity with FGD equipment has been superseded by a smaller retrofit programme coupled with the development of cleaner, gas-fired capacity by the newly privatised generating companies and others who are now able to enter the market. While these measures may enable the UK to meet its international commitments, the measures suggest that more demanding commitments, such as those accepted by some other member states, could also be achieved in the UK.

6.52 The tasks of controlling and reducing growth in NO$_x$ emissions represent a significant challenge. The negotiation of a new, Europe-wide, SO$_2$ Protocol and the eventual revision of the LCP Directive and NO$_x$ Protocol offer important opportunities for the UK. The critical loads approach, combined with atmospheric modelling techniques, allows preventive measures to be directed at the sources of emissions that cause the greatest environmental damage, hence achieving abatement in the most cost-effective manner. For SO$_2$ emissions, this could mean stricter emission limits, involving retrofitting with FGD equipment, for those power stations and
Plate 8  Invertebrate sampling in the river Colne, Hertfordshire.
Photograph by courtesy of Chris Westwood/Environmental Picture Library.

Plate 9  Water monitoring at a gauging station on the river Torridge, Devon.
Photograph by courtesy of Topham Picture Source.
Plate 10  The dry bed of the river Darent, Kent, in 1990.
Photograph by courtesy of NRA Southern Region.

Plate 11  Water pouring from an underground fissure in a chalk aquifer.
Photograph by courtesy of British Geological Survey.
Plate 12  Large bloom of *Microcystis* at Looe Pool, Helston in Cornwall.
*Photograph by courtesy of NRA South West Region.*

Plate 13  Hypertrophic river near Hitchin, Hertfordshire.
*Photograph by courtesy of Vanessa Miles/Environmental Picture Library.*
Plate 14  Acid emissions from a power station.  
*Photograph by courtesy of Stan Gamester/Environmental Picture Library.*

Plate 15  Liming of Llyn Brianne in Powys, Wales, by boat.  
*Photograph by courtesy of NRA Welsh Region.*
The map shows critical load values for 10 km squares of the Ordnance Survey national grid of Great Britain. The critical load for a given 10 km square is calculated from the water chemistry of one sample from a sensitive site in that 10 km grid square. For Scotland, samples were collected in 1990. Sampling of England and Wales began in 1991 and will be completed, along with waterbodies in Northern Ireland, in 1992.

The coloured grid squares represent the areas in which acid depositions are expected to have been reduced to the level of the critical load, or below, by that date. The white squares indicate the areas where critical loads are still likely to be exceeded taking into account planned reductions in SO₂ emissions.

Plate 16  Provisional maps of:

a) critical loads for sulphur deposition to freshwaters of Great Britain.
b) areas of Great Britain where critical loads for sulphur deposition to freshwaters are exceeded.
c) target loads for the acidification of freshwaters of Great Britain for the year 2005.

Photographs by courtesy of Dr K Bull/Institute of Terrestrial Ecology, Monks Wood. These maps were prepared for and funded by DOE.
Plate 17  Sewage treatment works, Stalham, Norfolk, showing (a) primary settlement tanks, (b) biological filtration and (c) dosing equipment for phosphate removal.

Photograph by courtesy of Anglian Water.

Plate 18  Polluted tributary of the river Mersey, Widnes.

Photograph by courtesy of Martin Bond/Environmental Picture Library.
Plate 19  Industrial and sewage pollution in the river Aire, Yorkshire. The white foam results from discharges from textile factories.

_Photograph by courtesy of Topham Picture Source._

Plate 20  Combined sewer overflow discharging into the river Roch, Bury. This overflow is no longer used.

_Photograph by courtesy of North West Water Limited._
Plate 21  Combined sewer overflow at Abbey Mills pumping station, East London.  
Photograph by courtesy of Robert Brook/Environmental Picture Library.

Plate 22  Discharge of animal grease and pollutants from an animal skin processing plant into the river Tees, Yarm.  
Photograph by courtesy of Hoffman/Greenpeace.
other fixed sources which cause the greatest harm. This would be consistent with the treatment of discharges of liquid effluents, where controls are related to the quality standards to be achieved in receiving waters.

6.53 We recommend that the Government should seek, in these international negotiations, agreement on a long-term aim of reducing acid emissions so that the critical loads are not exceeded in the UK and elsewhere in Europe. This should be done in the most cost-effective manner and to an agreed timetable which takes due account of the environmental damage that is being sustained and the costs and practical difficulties of achieving emission reductions. There are, however, environmental disadvantages associated with technologies to reduce acid emissions. We recommend that the best practicable environmental option should be considered in selecting the appropriate reduction methods in order to achieve an outcome which is most favourable to the environment as a whole. We also recommend that the Government should increase the resources it allocates to research on clean fuels and the opportunities for renewable energy developments. Consideration of the impact of acid emissions from motor vehicles is also

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**BOX 6.14 EC DIRECTIVES AND INTERNATIONAL AGREEMENTS TO REDUCE ACID EMISSIONS**

- **EC Directive 88/609/EEC on Large Combustion Plants (LCP).** The Directive requires the UK to reduce SO₂ emissions from large industrial sources existing prior to 1987 by 20% in 1993, 40% in 1998 and 60% in 2003, with 1980 emissions (3.9 million tonnes) taken as the baseline. Cuts of 15% by 1993 and 30% by 1998 on the 1980 level of NOₓ (1.11 million tonnes) from these sources are also required. The Directive is due to be reviewed in 1994. In 1989 (the most recent year for which figures are available), LCPs accounted for 37% of total NOₓ emissions, and in that year emissions of SO₂ and NOₓ had declined by 20% and 12% respectively from the 1980 level, although it is unlikely that this was due to positive steps to implement the Directive. To meet the UK's commitments under the Directive, approximately £6 billion is planned to be spent over the next decade on new, low SO₂ generating plants, such as combined cycle gas turbines (CCGT), on investments at existing plants, for example on flue gas desulphurisation (FGD) equipment and low NOₓ burners, and on alternative fuels, such as low-sulphur coal, for use in existing plants. The retrofitting of low NOₓ burners to the dozen major power stations, which represent about 70% of the coal-fired capacity, will be necessary to meet the Directive's targets for reducing NOₓ emissions.

- **UN-ECE NOₓ Protocol (GE.89-40897).** Requires the UK to reduce total NOₓ emissions to 1987 levels (2.6 million tonnes) by 1994, with further reductions thereafter. In 1989, total NOₓ emissions in the UK were 2.7 million tonnes. The need to comply with this Protocol will increase the pressure for additional cuts in emissions, possibly involving the retrofitting of more expensive selective catalytic reduction technology to large combustion plants. This technology is claimed to be performing well on German power stations. Measures to reduce NOₓ emissions from motor vehicles will play a key role.

- **EC Directives 89/458/EEC and 88/777/EEC.** Require a reduction in emissions, including NOₓ, from vehicles. Road transport emissions of NOₓ are currently split in the ratio 3:2 for cars (mainly petrol) and heavy duty vehicles (mainly diesel). Emission standards from 1992 will result in the use of three-way catalytic converters on new petrol-engined cars and are expected to lead to substantial reductions in emissions of NOₓ from this source over the next 10 to 15 years. Progressively tighter emission standards for diesel-engined heavy duty vehicles, which have been agreed for implementation in the EC over the period up to 1996, are also expected to produce substantial reductions in NOₓ emissions. The World Wide Fund for Nature has prepared projections of atmospheric emissions from road transport in the UK, on the basis of forecasts of traffic growth published by the Department of Transport. Although subject to considerable uncertainty, these projections indicate that total NOₓ emissions from road vehicles could fall by 50% or more by 2005, depending on the rate of traffic growth over that period and the rate at which new low-emission vehicles replace older ones on the road. Towards the end of the decade, however, total NOₓ emissions are projected to rise again as the effects of further traffic growth outweigh the effects of the withdrawal from use of older, high emission vehicles.
required. The benefits of developments in these fields would extend beyond protection of the water environment but measures of this kind, combined with careful land management, could play a useful role in the long term of reducing acid emissions and thereby reversing the acidification of freshwaters.
CHAPTER 7

SOME SOURCES OF POLLUTION

Introduction
7.1 Chapter 3 outlined briefly some of the main sources of water pollution and their effects. This chapter seeks to describe some of these sources in greater detail. It makes no claim to be comprehensive in scope: we have concentrated on examples of both point and diffuse source pollution which seemed particularly significant, or which we believed required further attention.

7.2 In reaching our recommendations we have drawn not only on the evidence we received but also on detailed reports, published separately, which were prepared for us by Environmental Resources Ltd and the Water Research Centre. They enabled us to cover a wider range of subjects than would otherwise have been possible.

7.3 What we have seen leaves us in no doubt about the great improvements in pollution control which are still required, nor about their high cost. Nevertheless, there are already encouraging signs of a new environmental awareness in some sectors of industry and elsewhere. Important changes are afoot and we discuss in chapter 9 the implications for pollution control in the future.

WASTE WATER PRODUCTION AND TREATMENT
Waste water production
7.4 Over 2 billion tonnes of liquid waste are produced in England and Wales each year by households and industry². This waste is disposed of either directly to waterbodies (including estuaries and the sea) or via the sewerage system, subject in each case to the consent of the appropriate body. Some untreated sewage enters freshwater via overflows from sewers and treatment works. In England and Wales, controls are applied by a number of authorities. HMIP regulates releases from prescribed processes to any environmental medium, subject to meeting the NRA’s requirements for discharges to water; the NRA regulates other discharges to water (see box 7.1); sewerage undertakers regulate discharges of trade effluent into their sewers subject to referral to the Secretary of State for prescribed substances.

### BOX 7.1 CONSENTS TO DISCHARGE EFFLUENT

Discharges to freshwater from point sources such as sewage treatment works (STW) and factories require the consent of the appropriate regulatory authority (NRA, RPA, DOE(NI)). The principle underlying the setting of discharge consent conditions is that the loading of pollutant in the receiving water must not exceed the latter’s assimilative capacity and that the waterbody should remain (or become) of a quality which is satisfactory for all its expected uses, as expressed in its quality objective. Consents therefore normally include numerical limits on the volume and concentration of some of the substances contained in the discharge. Those for discharges from STWs, for example, normally include limits for suspended solids, biochemical oxygen demand and, in some cases, ammonia, (though practice has varied widely from region to region). Consents for industrial discharges may cover many more determinands including organic pollutants and heavy metals.

Some discharges, for example, of cooling water, and from surface water sewers, combined sewer overflows and some small sewage treatment works, are generally subject to descriptive consent conditions. A typical descriptive consent for a small sewage works will authorise its discharge provided no trade effluent is accepted, the number of properties which may be connected remains below a specified number, the works receives proper maintenance and is operated “as far as is reasonably practicable” to prevent damage to the receiving waters.
Chapter 7

Domestic sources

7.5 In the UK more than 95% of households are connected to the public sewerage system. About 83% of the waste water they produce is treated at sewage treatment works (STW) discharging to inland waters and 17% is discharged to sea. Sewage from remaining households is usually disposed of to cesspits (whose contents require regular emptying and treatment at a sewage treatment works) or septic tanks where it is broken down by natural processes and the effluent discharged to soil or directly to waterbodies.

7.6 Although most domestic sewage is bio-degradable it contains many household chemicals which are not broken down or removed in the sewage treatment process or which are discharged without treatment from the sewers (for instance through storm overflows). We asked the Water Research Centre (WRe) to review the likely impact of chemicals used in the home, for example in cleaning products, cosmetics, paints, pharmaceuticals and pesticides, to assess whether they might have the potential to pollute receiving waters.

**BOX 7.2 SEWAGE TREATMENT**

At most large sewage works, treatment involves preliminary screening and grit removal, followed by primary sedimentation, and secondary treatment (see figure 7.1). The last consists of biological oxidation, normally using either percolating filters or aeration in 'activated sludge' tanks, followed by further sedimentation. Additional tertiary treatment, to improve suspended solids removal or to deal with specific contaminants such as phosphate, is sometimes provided. In 1986 about one per cent of treatment works in England and Wales provided tertiary treatment. The urban waste water treatment directive will require nutrient reduction from some STWs discharging into waters which are already, or are liable to become, eutrophic.

An efficient sewage works should remove at least 90% of the pollution load, defined as suspended solids and biochemical oxygen demand (BOD), yielding a treated effluent which is discharged to a watercourse and a sludge resulting from primary and secondary treatment which has to be disposed of. Physical separation before treatment is essential to remove non-degradable objects flushed down toilets (eg contraceptives). Substances which do not respond to physical separation or biochemical degradation are not removed in the treatment process.

The overall effect of sewage treatment is the destruction of a high proportion of the pathogenic organisms present in raw sewage or their removal in sewage sludge; similarly many obnoxious chemicals are either separated into the sludge or biodegraded. After the effluent is discharged, the processes of dilution and self-purification in the receiving water further lessen the harmful effects of the effluent and any undesirable constituents present.

7.7 Although WRC's study suggests that most of these substances, in the quantities used in the home, are likely to have little effect on the aquatic environment, it drew attention to some potential problems, notably the presence of metals in domestic sewage. Studies in several countries indicate that the contribution from residential areas to the metal loads at STWs, particularly of nickel, copper, lead and zinc, can be as much as 20% of the total released to sewers. Some of these metals are dissolved from water pipes and solder but others are contained in cosmetics, toiletries, medicines and domestic cleaners. Not all the metal load will be retained in the sludge at STWs; part will reach watercourses in the STW effluent. Nickel, in particular, has a low rate of removal from waste water during treatment. We recommend further research on the extent to which metals from domestic sources are reaching the environment. If household sources are found to be significant, their contribution will need to be reduced, for example, by changes in product formulation to reduce the use of metals.

7.8 WRC concluded that, apart from these metals and from nutrients, which are considered in chapter 6, normal usage of currently available domestic proprietary products was unlikely to threaten the aquatic environment. Dilution in sewers and treatment at STWs would normally be
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adequate to reduce concentrations to harmless levels. WRc did point out, however, that even where substances such as cosmetics, toiletries and medicines had been subject to extensive testing for possible human health effects, ecotoxicity testing had rarely been carried out. Some of these substances, for example antibiotics and oral contraceptive constituents, are being found in the water environment at levels which, though very low, may be biologically active. Medical treatments such as chemotherapy may also lead to the release of highly potent substances into the sewerage system. Investigation of their incidence is desirable and we recommend that an exploratory study be carried out into the presence of such substances in river waters and of their environmental effects.

Industrial Sources

7.9 Industrial processes produce large volumes of liquid wastes, many of which can be harmful to freshwater life unless adequately treated. The effect of such wastes on the natural state of the waters is to be seen in rivers such as the Mersey, the Yorkshire Don and Rother and the West Midlands Tame (see plates 18 & 25). Many heavy industries are located on certain estuaries, partly because of the assumed assimilative capacity of the waters. The decline of heavy industry in the 1980s removed some of the worst sources of pollution but others continue and legacies of contaminated land, abandoned mines and polluted river sediment also remain. Examples of these industrial legacies are illustrated in the work we commissioned from WRc on the Tame (see appendix 5) and are also considered later in this chapter.

7.10 The regulatory authorities now seek a degree of effluent treatment by industry calculated to enable water quality objectives to be achieved (see box 7.1). Sewerage undertakers are being obliged to improve the quality of STW effluents, particularly in relation to Red List substances, and hence to consider more carefully the effluents which they permit industry to discharge into their sewers. Substances which do not respond to biological treatment may not be accepted at all. Sometimes initial treatment is required before discharge into the sewer so that the industrial effluent will not harm the biological treatment process at the STW. Nevertheless, pollution continues and as older industries and practices decline, new ones create fresh pollution potential.

7.11 Complex discharges are difficult to monitor and control under the normal system of consents which, in practice, limit only a small number of determinands. Even those relating to large industrial discharges may routinely control fewer than 20 physico-chemical determinands. Many effluent components are very difficult to identify. They may vary considerably even when derived from manufacturing complexes where process consistency is high. These factors make it well-nigh impossible to assess the environmental significance of such discharges and hence to develop a realistic estimate of the ability of the receiving waters to assimilate them, to draw up consents which will provide adequate control, or to monitor the effluents comprehensively and accurately. There are also implications for pollution reduction strategies based on percentage reductions, or tight discharge limits for specific substances. To be effective, these strategies would require frequent monitoring of a very large number of determinands using very precise and accurate techniques. Where waters are subject to complex industrial discharges, regular programmes of biological monitoring may help draw attention to unrecognised pollutants and unanticipated environmental effects.

7.12 An approach increasingly in evidence in this country and abroad, is to move towards better selection and control of processes, recycling, and treatment within each industrial plant, with a view to minimising waste and reducing its environmental impact. Environmental pressures, concern about security of supply, but especially the increased cost of raw water are driving industry to minimise water use and hence the production of effluent. We welcome this development, which would receive additional impetus from the incentive charging scheme which we discuss in chapter 8.

7.13 The Centre for Exploitation of Science and Technology (CEST) proposed in a recent report the establishment, with the participation of representative industries based in a single river catchment, of a demonstration project intended to identify and publicise the environmental,
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financial and other benefits of cleaner processes. Its report also identified technical approaches to problems of waste water treatment but commented that the real need was to develop integrated systems for reducing the pollution discharged to the environment, rather than rely on isolated technical solutions.

7.14 Consented discharges of effluent are not the only cause of pollution from industrial sources. Industrial pollution incidents are also significant, accounting in 1990 for 17% (109) of the major pollution incidents in England and Wales (table 7.1 provides regional details of all incidents, regardless of severity).

Effluents from the textile industry

7.15 In order to explore issues raised by complex effluents, we asked Environmental Resources Ltd to review the effects on water quality of discharges from the textile industry. Chemicals are used at many stages in this industry, for example for dyeing and mothproofing, and to produce special finishes such as water repellence and flameproofing. The wastes therefore contain many potentially harmful chemicals, including organic and inorganic acids, alkalis, ammonia, heavy metals, phenols, and such mothproofing agents as pentachlorophenol and synthetic pyrethroids. Disquiet in the past about the environmental effects of the industry led to changes in the chemicals used and to improvements in waste treatment. For example, over 10 years ago, British industry stopped using the persistent organochlorine pesticide, dieldrin, for mothproofing.

<table>
<thead>
<tr>
<th>NRA</th>
<th>1987</th>
<th>1988</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anglian</td>
<td>180</td>
<td>169</td>
<td>213</td>
</tr>
<tr>
<td>Northumbrian</td>
<td>42</td>
<td>66</td>
<td>117</td>
</tr>
<tr>
<td>North West</td>
<td>336</td>
<td>338</td>
<td>267</td>
</tr>
<tr>
<td>Severn Trent</td>
<td>785</td>
<td>1,108</td>
<td>350</td>
</tr>
<tr>
<td>Southern</td>
<td>181</td>
<td>182</td>
<td>164</td>
</tr>
<tr>
<td>South West</td>
<td>252</td>
<td>341</td>
<td>339</td>
</tr>
<tr>
<td>Thames</td>
<td>190</td>
<td>323</td>
<td>385</td>
</tr>
<tr>
<td>Welsh</td>
<td>237</td>
<td>353</td>
<td>138</td>
</tr>
<tr>
<td>Wessex</td>
<td>52</td>
<td>160</td>
<td>403</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>537</td>
<td>620</td>
<td>426</td>
</tr>
<tr>
<td>Total</td>
<td>2,792</td>
<td>3,660</td>
<td>2,802</td>
</tr>
</tbody>
</table>

(Data up to 1988 from DOE Digest of Environmental Protection and Water Statistics 1988 and 1989 and provided by previous Water Authorities)

7.16 Although some factories discharge direct to surface water, most of the industry’s effluent is discharged to sewer. ERL found that the effects of the industry’s effluent are reduced but not eliminated by treatment in a sewage works; watercourses downstream of a sewage outfall can contain high levels of dye colour, mothproofing agents and other contaminants. The Tweed RPB reported that declining trout catches and an absence of macroinvertebrates in the Tweed in the late 1980s appeared to be linked to the presence of mothproofing agents in the discharge from a STW. In 1987 the sewerage undertaker installed an additional filter which is operated when high levels of the mothproofing agent are identified in the inflow to the sewage works. The river fauna is now recovering.

7.17 The Clyde RPB told us that one river in its area (the Annick Water) is polluted by a mothproofing agent at levels well in excess of those known to be toxic to certain species of
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7.18 Thus, despite improvements to the textile industry's effluents, problems still remain. ERL identified areas for research which might bring further benefits, including development of substitutes for some of the more harmful substances and work on more advanced treatment techniques before the effluents are discharged.

7.19 Timely recognition of environmental demands and prompt action by industry may help to avoid major compliance problems. When we met representatives of the textile industry, we were told that some companies were experiencing such difficulty in producing effluents free from pentachlorophenol (PCP) that they could see no other course than to close down or make illegal discharges. (see Box 7.3). Earlier recognition of the need for action might have enabled them to develop effective treatment processes or obtain uncontaminated supplies of raw material.

BOX 7.3 DISCHARGES OF PENTACHLOROPHENOL

In 1986, the EC Dangerous Substances Directive set an EQS of 2 micrograms per litre (μg/l) for pentachlorophenol (PCP) which should have been applied by 1 January 1988. Some sewerage undertakers have had difficulty in making certain sewage works comply with discharge consent conditions designed by the NRA to meet the EQS. At one sewage outfall PCP concentrations of 60 μg/l have been recorded, compared with a consented limit of 6 μg/l. The source of the pesticide was traced to discharges to sewer of water used to scour grey cloth impregnated with PCP in its country of origin, mainly in Africa and the Indian sub-continent. Although the textile industry is attempting to stop producers from using PCP, there has been a lengthy delay during which already treated stocks have been used.

7.20 To some extent, the textile manufacturers suffered from the legacy of previous practice, since diffuse sources were contributing high levels of PCP to the eventual receiving waters. To meet the EQSs for these waters no additional PCP from any point source could be permitted. Thus none could be accepted into sewers because PCP is not eliminated by sewage treatment. As we saw on the river Tame, it is not uncommon for the legacy of the past to constrain present practice in similar ways. As a result, considerable costs can be imposed either on dischargers required to provide very high levels of effluent treatment, or on society more generally in cleaning up derelict land and contaminated sediments (see Box 7.4).

BOX 7.4 RIVER TAME: POLLUTION FROM OLD TIPS

The river Tame rises in the Black Country and flows through the Birmingham conurbation. Its upper reaches have suffered a history of gross pollution by heavy industrial activity, old waste tips and overflows of sewage.

Over the years, many point sources of metal contamination have been tackled. The most recent involved expenditure by IMI plc of several hundred thousand pounds on effluent treatment. Seepage containing high concentration of heavy metals, mainly copper and nickel, continue to flow into the river Tame from two former waste sites at Slacky Lane and Bentley Mill Lane near Walsall. Between them they contribute about 6 tonnes a year of copper and 15 tonnes of nickel to the river. This amounts, in average conditions, to about one-sixth of both the copper and nickel loads of the Tame at its confluence with the Trent. Cleaning up the derelict land from which these metals arise would be costly but may be necessary in order to meet the UK's obligation to reduce List II substances discharged to the North Sea by 50%.

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Trade effluent

7.21 It is often appropriate to discharge trade effluent to sewer and treat it in a sewage treatment works (see box 7.5). In many cases this practice works well, producing a better quality effluent at the point of final discharge into a receiving water than would be possible from on-site treatment alone. Limitations of space, or hygiene requirements, may make on-site treatment impracticable or undesirable. For reasons of hygiene at food processing factories, for example, waste treatment plants are not normally required on the site. Where a choice exists between waste treatment on site or at the sewage works, trade effluent charges provide dischargers with a real economic choice about the cost of dealing with their wastes, a point we discuss further in chapter 8.

<table>
<thead>
<tr>
<th>BOX 7.5 LEGAL CONTROLS AND CHARGES FOR DISCHARGES TO SEWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject to certain conditions, the owner or occupier of any premises is entitled to have his drains or private sewer communicate with the local sewerage undertaker's system. This legal right to discharge excludes wastes produced in the course of a trade or industry (trade effluent), or substances which are expressly prohibited (for example, ones which might damage the sewerage system or the sewage treatment process).</td>
</tr>
<tr>
<td>Anyone wishing to discharge trade effluent to a public sewer must obtain the consent of the sewerage undertaker who may impose conditions specifying the quantity and quality of the effluent. These are based on the effect which the effluent will have on the performance of, and discharge from, the sewage treatment works and may require it to be pre-treated or detoxified before being consigned to the sewers. Consents are generally reviewed on a two yearly cycle. It is an offence to discharge trade effluent to sewer without a consent or in breach of conditions. The undertaker normally levies trade effluent charges intended to recover the costs which the undertaker incurs in treating and disposing of the effluent (see box 8.7). The undertaker must refer any application to discharge trade effluent which contains a prescribed substance or derives from a prescribed process to the Secretary of State, who must determine whether the application may be granted and, if so, under what conditions. There are parallel systems of trade effluent consents in Scotland and Northern Ireland.</td>
</tr>
</tbody>
</table>

Sewage treatment

7.22 The proportion and composition of trade effluent in sewage depends on the extent and nature of industrial activity in the sewerage area and varies enormously. Table 7.2 shows typical ranges for a selection of components of raw sewage and percentage removal by primary and secondary treatment. Figure 7.1 shows the methods employed in STWs. While most discharges of trade effluent to sewer have controls on quality and quantity, domestic sources and urban run-off are, in effect, uncontrolled. Substances which do not respond to physical separation or biochemical degradation are not removed by treatment. Sewerage undertakers operate some 6,000 STWs, discharging the effluent to waterbodies (see box 7.2). The residual sludge is dumped, incinerated or, when it is not significantly contaminated, used as a soil conditioner.

Small STWs

7.23 Effluent from sewage works serving populations of less than 250 and from emergency overflows from sewage pumping stations can be covered by descriptive consents where there are no known toxic sources (see box 7.1). Some of these STWs discharge into small streams of otherwise high quality in rural areas. Such streams can be seriously affected by the effluent. We consider that, in some cases, it may be necessary to build additional storage capacity to cope with sudden surges of sewage rather than allow it to flow untreated to the watercourse. We recommend that, where receiving waters are sensitive to pollution, the regulatory authorities should replace
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Figure 7.1 Sewage treatment and disposal processes

Not all the stages and process routes shown in this schematic diagram are present in every STW but typically PRELIMINARY, PRIMARY and SECONDARY processes are represented in some form at all STWs discharging to Inland waters.

Raw Sewage

- Screening
  - Maceration
  - Grit Removal

Preliminary Processes

- Storm Water Settlement
  - Overflowed Storm Water

Primary Processes

- Retained Stormwater

Secondary Processes

- Sludge Treatment
  - Typically Digestion
  - Dewatering
  - Incineration

Tertiary Processes

- Sludge Treatment Liquors
  - Part Sludge Recirculation (A.S.)
  - Sludges (S.F.) (M.S.)

- Sedimentation
  - Typically Activated Sludge (A.S.)
  - Percolating Filters (P.F.)

- Oxidation:
  - Typically Activated Sludge (A.S.)
  - Percolating Filters (P.F.)

- Settled Sludge
  - Sludge Treatment
    - Digestion
    - Dewatering
    - Incineration

- Straining:
  - Typically Sand Filtration (S.F.)
  - Broad Irrigation Micro Straining (M.S.)

- Nutrient Reduction

Disposal
### Table 7.2
**Performance of sewage treatment systems**
Adapted from CES Ltd, Study of Coastal Sewage Discharges, 1990

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw</th>
<th>% Removal</th>
<th>Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids</td>
<td>250–400 mg/l</td>
<td>50–65</td>
<td>90–95</td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>300–500 mg/l</td>
<td>30–40</td>
<td>90–95</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>250–1000 mg/l</td>
<td>30–40</td>
<td>80–90</td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>40–65 mg/l</td>
<td>10–20</td>
<td>25–45</td>
<td></td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>15–25 mg/l</td>
<td>5–15</td>
<td>20–40</td>
<td></td>
</tr>
<tr>
<td>Total Coliforms</td>
<td>3–500x10⁹/100 ml</td>
<td>30–60</td>
<td>90–99</td>
<td></td>
</tr>
<tr>
<td>Faecal Coliforms (TTC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viruses</td>
<td></td>
<td>0–50¹</td>
<td>75–100</td>
<td></td>
</tr>
<tr>
<td>Organics (eg Pesticides)</td>
<td></td>
<td>20–50²</td>
<td>70–100⁴</td>
<td></td>
</tr>
<tr>
<td>Individual Heavy Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>excl. Nickel¹</td>
<td>100–400 µg/l</td>
<td>30–50²</td>
<td>50–70</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>&lt;0.02 mg/l</td>
<td>20–30</td>
<td>30–50</td>
<td></td>
</tr>
<tr>
<td>PFU = plaque forming units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Virus removal highly variable; figures quoted range from 0–97%. Removal often depends on Suspended Solids concentration.
2. Typical value.
3. Very variable – also depends on Suspended Solids concentration.
4. Variable.
5. Cadmium levels also low: 5–50 µg/l

the descriptive consents with numerical ones so that the quality of the waters can be properly safeguarded. This would provide an added incentive to STW operators to achieve the high standard of operation at such works discussed below.

7.24 Continuous, consistently satisfactory operation at small, unmanned sewage works is difficult to achieve. Pipes and pump clearances are small and prone to blockages and, for the same reason, the holes on the distributors of percolating filters require regular cleaning. If small works are not desludged frequently enough, they further hazard the treatment process. Where STWs have staff in situ these matters can be dealt with as they arise. To man such small works continuously, however, would rarely be an efficient use of resources. There is therefore a risk that lengthy periods of pollution may occur without remedial action being taken. The installation of telemetry can assist in monitoring pumping machinery in particular, but we also recommend frequent regular visits by peripatetic operators, who can rectify faults on the spot, in order to minimise periods of unsatisfactory operation. The regularity of visits should depend on operating and maintenance experience and the sensitivity of the receiving waters to the breakdown of equipment. We also recommend that more consideration should be given to improving the design of small STWs so that they provide effective and reliable treatment.

**Large STWs**

7.25 Larger sewage treatment works are either manned and monitored continuously or during the working day, and are intrinsically more reliable. Failures will not ordinarily go unnoticed even for short periods. Treatment is normally carried out in multiple units at each stage of the process and it is consequently easier to carry out routine maintenance without adverse effects on performance. Even when it is necessary to take a unit out of use for major repair, the sewage flow
can be divided between those remaining in service, minimising the shortfall in treatment capacity. It is therefore disappointing that better results are not found.

**STW effluent standards**

7.26 In 1912, the Royal Commission on Sewage Disposal recommended that sewage effluents should not contain more than 3 parts per 100,000 of suspended matter and not take up more than 2 parts per 100,000 of dissolved oxygen (now normally expressed as 30 mg/litre suspended solids and 20 mg/litre BOD). These figures were calculated by considering the effect of a discharge into clean receiving waters with a dilution factor of 1 to 8. Although the Commission accepted that the quality and quantity of river water were highly important local conditions to be taken into account in framing standards, it did not consider that effluent quality should be determined automatically by these factors, since this would entail administrative complexity, unequal economic burdens between local authorities in the same watershed, and differing standards of purity without any corresponding advantage. It recommended that its proposal should be regarded as the normal standard for effluents but acknowledged the existence of some exceptional cases calling for either a more stringent, or more relaxed standard. This 30/20 standard was subsequently applied to the majority of discharges.

7.27 In 1978, the National Water Council (NWC) proposed a new system under which Water Authorities would set River Quality Objectives which would in turn provide the basis for setting discharge consent conditions. This rather different philosophy meant that 'a potential discharger may be faced with more stringent conditions in one area than another'. Water Authorities were exhorted to complete the review of consent conditions, at least for major discharges, within two years.

7.28 The first review of consent conditions in 1979/80 was followed by a further review in 1983/84 shortly before the implementation of Part II of the Control of Pollution Act 1974 (COPA). The aim was to bring consents more closely in line with the historic performance of the works. It resulted in an overall relaxation of standards and loosened the connection between consents and the quality requirements of receiving waters. In December 1988 an accelerated investment programme of about £1 billion was announced. This was designed to bring substandard sewage treatment works into compliance with their consents by 1992. Water authorities were granted over 800 time-limited consents for works where improvements were programmed for completion by March 1992. For certain small works where no remedial work was planned 54 longer term variations were issued. The time-limited consents contained two sets of conditions. Temporary standards were intended to prevent further deterioration in effluent quality while allowing time for improvements to be made and were automatically replaced by the more stringent set at a date which allowed for completion of remedial works. These latter conditions are generally in line with those in the previous consents but in some cases are stricter.

7.29 It is clear from the above paragraphs that for most of the century, the financial circumstances under which local authorities and then water authorities operated, played an important role in determining the quality required of sewage works' effluent. This may go some way to explain why river quality surveys have continued to identify substantial lengths of low quality water. Moreover the position was exacerbated by non-compliance with consent conditions. The Jeger Report, published in 1970 (before the creation of the water authorities in England and Wales) found that 60% of sewage treatment works were discharging final effluents in breach of their consents. In 1978 the National Water Council commented that 'there was an understandable tendency for discharge consent conditions to be set which were regarded as targets to be achieved over a period of years. Only River Authorities could prosecute for failure to comply with discharge consent conditions ... and they were expected to act reasonably by prosecuting only for flagrant and careless breaches of consent conditions'. One of the spurs for the NWC review was the fear that implementation of COPA would have opened the way to prosecution of Water Authorities for non-compliant discharges. These twin failures - to link consents with the requirements of the river in preference to those of the discharger, and to match discharges to the consents supposedly governing them - have continued to bedevil pollution control.
### Table 7.3
Sewage treatment works: \(^1\) non-compliance; 1986–90 England and Wales

<table>
<thead>
<tr>
<th>NRA region</th>
<th>Number tested</th>
<th>Works in breach of consent</th>
<th>Percentage of works tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anglian</td>
<td>774</td>
<td>754</td>
<td>748</td>
</tr>
<tr>
<td>Northumbria</td>
<td>196</td>
<td>182</td>
<td>178</td>
</tr>
<tr>
<td>North West</td>
<td>458</td>
<td>448</td>
<td>441</td>
</tr>
<tr>
<td>Severn Trent</td>
<td>762</td>
<td>742</td>
<td>751</td>
</tr>
<tr>
<td>Southern</td>
<td>282</td>
<td>274</td>
<td>271</td>
</tr>
<tr>
<td>South West</td>
<td>188</td>
<td>219</td>
<td>228</td>
</tr>
<tr>
<td>Thames</td>
<td>374</td>
<td>379</td>
<td>378</td>
</tr>
<tr>
<td>Welsh</td>
<td>668</td>
<td>611</td>
<td>650</td>
</tr>
<tr>
<td>Wessex</td>
<td>272</td>
<td>270</td>
<td>272</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>380</td>
<td>351</td>
<td>354</td>
</tr>
<tr>
<td>England and Wales</td>
<td>4,354</td>
<td>4,230</td>
<td>4,271</td>
</tr>
</tbody>
</table>

\(^1\) Works with numerical consents and tested for compliance

Source: former water authorities: National Rivers Authority
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STW compliance with consents

7.30 It is therefore not surprising that, in the circumstances referred to above, effluents from sewage treatment works have frequently failed to comply with consent conditions (see table 7.3). Non-compliance has fallen substantially over the last five years but the 8% figure for 1990 means that 333 STWs failed on occasions to meet their consents. There are notable regional variations in non-compliance: in the south-west, over a quarter of the works tested in 1990 still failed to comply with their consents. The NRA estimates that in 1990 12% of works in England and Wales (about 450 works) still failed on occasions to comply with their long term consent conditions.

7.31 In Scotland comparable data on discharges are available for the years 1975, 1982, 1985 and, in part, 1988. They show that in 1988, 73% of treated discharges entered inland waters and 31% of these were unsatisfactory or borderline. There was no improvement over the 1982 and 1985 figures. The number of unsatisfactory overloaded STWs fell from 158 in 1982 to 132 in 1985, forming 69% and 55% respectively of unsatisfactory/ borderline discharges. Throughout Scotland 24% of all discharges were causing a change of watercourse quality of one or more classes in 1985. It is important to note that in Scotland, unlike England and Wales, there has been no relaxation of consent conditions and percentiles are not used to assess compliance.

7.32 There has been a serious lack of investment going back many years. It is deeply disappointing that the remarks we make in our present report echo so closely those made by the Commission twenty years ago in commenting on the Jeger Report. The accelerated investment programme announced in December 1988 is intended to bring many substandard sewage treatment works into compliance with their long-term consents by the target of 1992 but this is only a first step. Total planned expenditure is already rising sharply (see table 7.4) but more will be required to cope with future growth, tighter standards and to maintain compliance at existing STWs in the post 1994/95 period.

Table 7.4: Planned expenditure on sewage treatment and disposal in England and Wales

(£M 1990/91 prices)

Note: The 1995 to 1999 forecast will be formally updated in the 1994 periodic review.
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7.33 The effects of under-investment were also pointed out by HMIP in its report covering English and Welsh STWs. The Inspectorate identified the most common reason for failure to meet consents in 1988/89 as hydraulic and biological overloading, mainly as a result of population growth. It said that in some cases this was exacerbated by poor liaison with local planning authorities. Other factors were also identified. Inadequate design had led to unsatisfactory results. In some STWs, trade effluent had caused biological overloading and subsequent failure. Shock loads and accidental discharge from factories to sewers were also a factor. Regular trade effluent was cited as the cause of non-compliance by 4% of STWs in 1988. Where this is the case, either the consents to discharge to sewer require revision or they are not being complied with. The remedy is in the hands of the sewerage undertaker who should revise the consents or enforce them properly, to eliminate this cause of failure.

7.34 Poor operation and maintenance was also reported to contribute to non-compliance. The tighter control regime being imposed by the NRA should provide a sharp spur but we believe that for many treatment works a fundamental review of operational practices and maintenance experience will be necessary in order to comply consistently with consents. Training of operational personnel in both routine and emergency procedures is of great importance and we recommend that where casual training methods still persist, they should be superseded by formal training schemes leading to nationally accepted proficiency standards recognised by the award of a certificate. Adequate manning levels are, of course, also required.

7.35 A further important factor lies in the design of sewage treatment works themselves. Some, although adequately designed for their original purposes, have been extended to meet increased flow or more stringent consent conditions, or modified to reduce maintenance or staffing requirements. We recommend that when any such extensions or changes are contemplated, the whole treatment process should be subjected to rigorous analysis using process design techniques so as to minimise unforeseen effects and optimise the value of the investment made. In most cases the process design analysis, whether for a new works or for modifications to an existing one, should form part of an operational manual so that the designer's intentions are clear to operators.

Improvements in performance

7.36 In terms of pollution control, the measures which have at last been initiated may be no more than a first step. For the most part the work in progress is aimed at reducing the most damaging effects on rivers of major discharges having a high suspended solids or biochemical oxygen demand. Even here, novel approaches to sewage treatment may permit higher standards of effluent to be achieved. In a study for DOE in 1990, Consultants in Environmental Sciences Ltd reported research suggesting that biological treatment combined with membrane filtration might have the potential to do this. CEST also stressed the advantages of membrane filtration in its report. Special treatment may be needed of substances which are not rendered harmless by the normal operation of the STW or by natural biodegradation. In addition phosphate and nitrate may need to be removed at sewage treatment works. Phosphate is discussed in chapter 6. Nitrate is formed when sewage effluent is treated to reduce concentrations of ammonia. Nitrate levels are already high in many rivers and in some cases a further increase may not be tolerable. Further expenditure may therefore be needed in order to remove nitrate (and phosphate) especially from effluents discharged to any waters designated as sensitive under the EC urban waste water treatment directive. This includes those used for the abstraction of water for drinking. The directive does not, however, require nutrient removal in STWs serving population equivalents of less than 10,000. Like the House of Lords Select Committee on the European Communities in its recent report, we recommend the application of nutrient reduction to STWs regardless of their size if the condition of the receiving waters merits it. As the Select Committee warns, the cost implications of the directive (including those relating to the treatment of coastal discharges) 'are very substantial'. Largely because coastal discharges will require treatment, it will also increase considerably the volume of sewage sludge requiring disposal.

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Consents
Defects in consents to discharge waste water

7.37 Improvement in the quality of freshwater has been impeded not only by the factors discussed above but also by defects in the way both industrial and STW discharge consents have been set and enforced. We were told by the NRA that it had inherited a variety of discharge consents granted to industries or sewage treatment works at different times and framed in different ways. It believed that at the beginning of 1990 about 139,000 consents were probably active, of which 12,000 were regularly sampled.

7.38 The NRA was aware of several other criticisms. Especially in the case of sewage treatment works, the range of specified determinands is limited and their application inconsistent, notably for ammonia (see figure 7.2). Consents for industrial discharges require absolute compliance while for sewage treatment works only 95% of samples are required to meet the limits. Many consents have been inadequately enforced in the past. Many combined sewer overflows and other previously unconsented discharges were given deemed consents when the NRA was established. Few discharges are measured by volume and this, together with the existence of descriptive consents for small STWs, makes it doubtful that the correct relationship has been established between consents and the quality objectives of the receiving water. Even the registers of consents themselves, not being produced consistently throughout the NRA regions, are cumbersome and difficult to use.

The Kinnersley Report

7.39 A working party was set up to address the problems of discharge consents and compliance policy. It made, in the Kinnersley Report, a number of detailed recommendations about the form that discharge consents with numeric limits should take. These covered all direct discharges to water including septic tanks and other small discharges. The main recommendations were:

* All numeric consents, including those for STWs, should contain absolute limits to protect receiving waters against extremes in effluent quality.
* All discharges to vulnerable receiving waters should additionally contain a percentile limit to control normal operational quality.
* There should be a more consistent application of limits for ammonia in all consents to which this is relevant.
* Trials should take place to assess whether total organic carbon (TOC) and turbidity would be suitable replacements for BOD and suspended solids in consents for many discharges. Neither BOD nor suspended solids is amenable to continuous monitoring and BOD also suffers from being an analytically unreliable test requiring 5 days to carry out.
* The awareness of dischargers about the quality of their effluents should be improved by encouraging more self-monitoring and improving communications with the NRA.
* A formal system of warning notices should be introduced for dischargers whose effluents risk breaching consent limits.

7.40 After taking into account the representations received on publication of the report, the NRA has now accepted the recommendations that absolute and percentile limits should be set on all consents. It has decided that the latter should accord with the provisions of the EC urban waste water treatment directive which requires that all STWs providing secondary treatment must, under normal operating conditions, always stay below an absolute limit and stay below a lower limit for 95% of the time. Controls on ammonia will be increased and will be based on the relevant statutory water quality objectives, once they have been set. The NRA will look at all options for oxygen depletion measurement techniques to enable monitoring of major discharges to be carried out more regularly and rapidly than hitherto. We consider that this action, when fully implemented, will resolve much that is unsatisfactory about present waste water consents. We discuss in chapter 9 the aspects of the Kinnersley Report relating to enforcement.
Figure 7.2  Sewage treatment works: application of numeric limits (by NRA region)

Sewage treatment works with suspended solids limits
(excluding minor STWs serving <250 population)

Sewage treatment works with BOD limits
(excluding minor STWs serving <250 population)

Sewage treatment works with ammonia limits
(excluding minor STWs serving <250 population)

As at Dec 1988

7.41 We have already noted the clear advantage of adopting determinands which enable major discharges to be monitored more regularly and rapidly than hitherto. We therefore support the proposed trials to assess the usefulness of TOC and turbidity as means of assessing water quality. Research into more rapid tests of BOD may also be fruitful.

7.42 We understand\(^3\) that consent limits on suspended solids (SS) are often derived by arbitrarily applying a factor to the BOD limit in the consent. Where the effluent is rich in degradable matter, the resultant SS limits appear to have little, if any, additional environmental benefit. We recommend that suspended solids limits should be determined by reference to the nature of the effluent and the quality objective of the receiving waters.

**Combined sewer overflows**

*The legacy*

7.43 We have so far discussed some aspects of pollution caused by treated effluent. In addition, some severe river pollution results not from defective controls or inadequate treatment but from overflows on combined sewers which are designed to spill excess flows at times of heavy rain (see box 7.6 and plate 20). Intermittent river pollution also occurs from separate sewerage systems whenever rainwater drains from highways and paved areas (see box 7.7).

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**BOX 7.6 COMBINED SEWER OVERFLOWS**

Most of the older urban communities in the UK are served by sewerage systems which carry both foul sewage (including trade effluent) and surface water run-off to a sewage works for treatment. These are known as combined sewers.

During times of heavy rainfall or rapidly melting snow, flows in combined sewers are often 20 times, and may be over 100 times, the average flow of foul sewage in dry weather. Sewers and pumping stations large enough to carry the whole of such flows would be intrinsically very costly and would imply very large (and hence also very costly) sewage treatment works. Such large sewers would be unsatisfactory hydraulically for long periods and, because flows would be less brisk, the problems of solids deposition and putrefaction would be exacerbated.

Sewers are therefore generally designed to carry a maximum flow much less than 20 times the dry weather flow. Overflows are incorporated into sewerage networks to spill flows which exceed the capacity of the system as a whole, including the treatment works. Mostly they consist of a device such as a weir for separating the excess flow which is then discharged untreated from the overflow chamber to the nearest suitable watercourse, either directly or through relief sewers. In the past, available methods of analysis for the design of overflow systems were crude and there was no common approach on design criteria though the practice evolved of setting storm overflows to operate at six times the dry weather flow of the sewer.

Pollution control legislation requires that all discharges – including those from combined sewer overflows – are consented by the regulatory authorities. Current practice is to require that a stated 'pass forward' flow is retained within the sewer and that overflow begins only when this rate of flow is exceeded. Conditions are not imposed as to the quality of the discharge because they would be unenforceable.

7.44 In both combined and separate sewerage systems the polluting effects of surface run-off are particularly evident at the start of a rainstorm or rapid thaw. In combined systems, the effects are increased by the re-suspension of sediments from foul sewage, producing a 'first flush' of much greater strength than normal sewage. We were told that a level as high as 1600 mg/l chemical oxygen demand (COD) could occur. This might be expected to have a severe effect on aquatic life in the river at a time when it may also be under stress from natural consequences of heavy rainfall, for example, as result of sediments in the river being disturbed.
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7.45 In some instances, holding tanks have been constructed adjacent to the sewer, or incorporated in it, to trap and hold the highly polluting first flush until sewer flows fall to the point where there will be no spillage from the system. It is then passed forward to the treatment works for processing. Such solutions can be costly to build and maintain, but may nevertheless be a cost-effective means of protecting receiving waters. Although it may be difficult to site storage tanks in urban areas, we were told by North West Water that in their experience it was generally possible for them to be installed satisfactorily. There is evidence that such solutions are at least as effective in protecting the receiving water as wholly separate systems (see appendix 5 and box 7.7). We believe it is opportune to question the current policy of adopting separate systems as the best means of minimising river pollution from surface water. We recommend that a radical reappraisal be undertaken of the polluting effects of untreated, intermittent surface water discharges from separate sewerage systems.

<table>
<thead>
<tr>
<th>BOX 7.7 COMBINED VERSUS SEPARATE SEWERS</th>
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<tbody>
<tr>
<td>For some years it has been the practice in new developments and where substantial upgrading of older systems was required, to provide separate sewers for foul sewage and for surface run-off. No overflow from the foul sewers is then permitted and the surface run-off is discharged to the nearest suitable watercourse. This can enable costs to be saved in the provision of sewage treatment facilities.</td>
</tr>
<tr>
<td>This approach has disadvantages however. Where existing systems are to be upgraded, the cost of separating combined sewers is considerably greater than that of improving the existing combined system. Surface water is itself polluting since it is contaminated with residues washed from roads and other paved areas, particularly after long, dry spells, and where activities such as street markets are held. The intermittent nature of such discharges means that they are not amenable to dedicated biological treatment systems which require a fairly constant feedstock. It has been demonstrated that the pollution load discharged from a separate sewerage system serving urban areas is at least equal to that discharged from a properly designed and constructed combined system (see paragraph 65 and table 11 of appendix 5). Experience also shows that connections of sewage or industrial waste are often wrongly made to surface water sewers. Some practitioners therefore consider that well designed, constructed and maintained combined systems are preferable to separate systems.</td>
</tr>
</tbody>
</table>

7.46 Despite some improvements, the problems of combined sewer overflows remain acute. Poor sewer and overflow design, and failure to invest to cope with increasing flows from the population and from ingress of groundwater to ageing sewers have contributed to widespread operation of overflows at levels less than six times dry weather flow. Sometimes overflows even operate at peak daily flows in dry weather. In some areas there are too many overflows and, where they are grouped along a short stretch of water, their effect on aquatic life can be highly damaging. In addition, the presence of recognisable, sewage derived solids in rivers is unacceptable on amenity grounds and is a cause of concern to sewerage undertakers, the NRA and the public alike.

7.47 These problems were considered by a Technical Committee on Storm Overflows and the Disposal of Storm Sewage which was established in 1955. The Committee attempted to devise a formula for setting overflows that took account of river quality, flow and use but concluded that there were too many unknown factors to make it workable. It was, however, able to recommend what it described as 'a modest improvement' in the normal overflow setting of six times dry weather flow\(^2\). This, known as 'Formula A', was still based on the dry weather flow, but adjusted to take account of population and industrial effluent discharged from the area served by the system. The Report of the Technical Committee led to the general adoption of 'Formula A', with the encouragement of the then River Authorities which promoted its use when considering discharge consents for new overflows. The Technical Committee hoped that improvements in technology and further research and experience would eventually enable account to be taken of the sensitivity of the receiving stream and its ability to cope with periodic discharges from the overflow.

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7.48 The failure to relate overflow to river needs has continued to the present day and it puts at hazard the attainment of target quality for the river system. It also distorts the correct pattern of investment in the sewerage system. Some 10% of inland rivers in England and Wales have been classified as of class 3 or 4 quality. The majority of these are in the most heavily urbanised and industrialised areas of the North-West, Yorkshire and the West Midlands. Of the 20,874 overflows in England and Wales, 42% are in those three regions. North West Water Ltd has estimated that 276 km of inland rivers in its region will not attain their NWC class 2 target unless these discharges are adequately controlled. They are a significant factor in bringing a further 900 km up to target. A high concentration of combined sewer overflows is one of the most serious sources of pollution in the river Tame in the West Midlands whose upper reaches are class 4 in the NWC scheme. Purification lakes were constructed some years ago at Lea Marston in order to improve the quality of the entire river and one of their benefits is a notable improvement in the quality of the Tame downstream of the lakes during heavy rain, a time when storm overflows are operating. In rainy weather in January 1990, for example, suspended solids concentrations of over 300 mg/l upstream were reduced by the lakes to 80-90 mg/l, (see figure 7.3).

Figure 7.3 Purifying effects on river Tame of Lea Marston lakes

7.49 There has been a sustained effort to provide means of analysing sewerage networks under flow stress and many computer based design aids have now been developed. They are generally used to assess the behaviour of sewer networks under a wide range of patterns and intensities of rainfall and snow-melt. They identify areas of stress and enable optimisation of the system capacity by modifications and additions, and they are used to improve the performance of storm overflows. In addition, in 1986 the second edition of the Sewerage Rehabilitation Manual, promoted by the sewerage undertakers, included an interim procedure to minimise combined sewer overflows in order to meet river requirements.
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Possible Improvements

7.50 Improved methods of control would be based on more information about the nature and volume of discharges and their effects on the receiving waters. They would take account of the episodic nature of the discharges and the likelihood that these will arise when the rivers are themselves carrying increased flows. A major research programme, the Urban Pollution Management programme, has been put in hand to improve the management of sewer and sewage treatment systems and their interaction with receiving waters. It has identified the need for improvements in the following areas:

—environmental standards for transient pollution events;
—rainfall inputs for flow simulation models;
—sewer flow quality simulation models;
—dynamic sewage treatment works models;
—river impact models; and
—engineering solutions to improve urban drainage system performance.

The programme seeks to develop an agreed and objective framework for the management of urban waste water discharges in accordance with environmental quality objectives and in full recognition of the legislative requirements.

7.51 The key to devising acceptable levels of storm overflow operation which take account of the needs of the receiving river lies in understanding how intermittent discharges affect the biota. WRc has produced two reports on 'Proposed Water Quality Criteria for the protection of aquatic life from intermittent pollution' dealing with dissolved oxygen and ammonia respectively. The development of quality standards which take account of the frequency and duration of rainfall, of how often storms of specified magnitude recur, and of their effect on aquatic life, is crucial to the whole approach and is not, we understand, being addressed in this way elsewhere in the world. The methodology being developed in the UK aims to deal with discharges from overflows in a similar way to those from other point sources, in that standards are designed to meet the needs of the receiving waters (as expressed in EQOs) instead of being based on fixed emission limits.

7.52 Given the vast scale of works needed to contain within sewerage systems the volumes of storm waters which may be reasonably anticipated, it would be unrealistic to look to the elimination of overflows as such. We therefore welcome both the modelling studies which will help to identify critical points where cost-effective improvements can be made and the developments aimed at linking overflow operation with the riverine EQO system. We hope for the speedy completion of the development programme and the adoption of its results by sewerage undertakers.

7.53 Modern technology now has the potential for a high level of control of sewerage systems. During the later parts of long periods of rainfall, for example, discharges from overflows may be very dilute and no more polluting than treated STW effluent. It may then be better for an overflow to discharge directly to a river rather than pass forward to a STW. In theory it would be possible to modify system performance accordingly. Although this development is in its infancy we understand that in Marseilles storm overflows are controlled in this way in order to ensure compliance with the bathing waters directive. In the long term, such control systems may prove practical and cost-effective. We would support their further development, provided they can be made sufficiently robust.

7.54 Sewerage undertakers in England and Wales plan to invest £200m on storm overflows between 1989 and 1995\(^2\). To them it is important to ensure that the right balance is struck between protecting the environment and cost. We have recommended in Chapter 4 a water quality plan for each river catchment which will enable priorities for pollution control to be set. In certain catchments, high priority will be needed for measures to remedy unsatisfactory overflows.

7.55 We believe storm overflows are often a significant source of pollution and we are impressed by the work being undertaken on behalf of the sewerage undertakers and the NRA to improve
understanding of the problem and formulate mutually acceptable solutions. We commend this work. We urge that, in the mean time, the tasks of identifying overflows, eliminating them where possible, and of making short term improvements by minor modifications to sewerage systems and to overflow structures, should go ahead unabated and with all urgency.

CONTAMINATED LAND

Introduction

7.56 Land may be contaminated by a wide range of activities, including industrial use, the disposal of wastes, mining or quarrying. Soil has a limited capacity to absorb, degrade or attenuate the effects of pollutants but when this capacity is exhausted, polluting substances may be leached out of the soil into surface and groundwater. As other sources of water pollution are brought under control, the hazards posed by diffuse flows from contaminated sites are becoming increasingly apparent. The Commission's Eleventh report, 'Managing Waste: The Duty of Care', discussed in detail all aspects of the environmental impact of the disposal of waste and touched on other ways in which land may be contaminated. For the present study we commissioned the Water Research Centre (WRc) to provide more recent information on water pollution from waste disposal and from contaminated land. Much of the text which follows is based on the reports which WRc prepared for us.

Industrial Sites

7.57 Information about past industrial activities on specific sites is often unreliable or non-existent. The extent of industrially-contaminated land in the UK has recently been estimated, from data collected for the 1988 survey of derelict land, by identifying those categories of land use which carry a strong likelihood of industrial contamination. On the basis of these estimates DOE considers that some 27,000 hectares of derelict land in England might be contaminated. A survey published by the Welsh Office in 1988 identified about 4,100 hectares of contaminated land in Wales, excluding sites of less than 0.5 hectares and sites in current use. The House of Commons Environment Committee inquiry on Contaminated Land reports estimates that perhaps 50,000 hectares (including land currently in use) might be contaminated. Some, but not all, of this contaminated land is a pollution risk to surface or groundwater.

7.58 Investigations of former gasworks sites for example, have found evidence of groundwater pollution long after operations at the sites had ceased. Phenol and cyanates continued to leach from a gasworks site in Fife which had been disused for 30 years. Significant concentrations of phenol were found at a distance of some 400m from the site, threatening the quality of water from a public supply borehole. Water in an industrial abstraction borehole in a chalk aquifer in Essex was found to be polluted by tar which had probably originated in the local gasworks. There are also cases of surface water being polluted. Gasworks wastes, including tar acids, a sludge rich in sulphate and oil, were deposited for about 60 years in ponds formed in an old pit adjacent to the river Lee, Hertfordshire, polluting the river gravels over a wide area. Extensive remedial measures were necessary to prevent pollution of the river itself. Investigations of aquifers under industrialised urban areas have revealed extensive pollution of groundwater by organic solvents (described in greater detail in paragraph 5.14 and box 5.3). Such pollution is typical of aquifers under urban industrial areas, particularly where groundwater levels are close to the surface or the aquifer is unconfined.

7.59 Pollution may not be detected until a site is being redeveloped. For example, contamination of the soil and groundwater under a small engineering site in the West Midlands was discovered only when it was noticed that foundations for a building extension smelt strongly of solvents. Former activities on the site had included metal cleaning and paint spraying. As the extent of contamination increased with depth, it was decided to seal the foundations rather than excavate the contaminated material; the pollution source therefore continued to contaminate the groundwater. In another case, chemicals were found flowing underground from an industrial site to a neighbouring village. It was proposed to construct a barrier around the site to prevent further migration of solvents. Work to make the site safe has been in progress for the past 15 years.

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7.60 In the UK it has often been the practice either to cover contaminated land in order to allow redevelopment to take place or to remove the contaminated soil and dispose of it to landfill. Neither solution necessarily safeguards groundwater. Remedial techniques are, however, under investigation and in certain cases are being used to decontaminate soil. Recently, the Government has encouraged the use of these techniques in projects funded under the Derelict Land Grant Scheme. A programme of research at Warren Spring Laboratory, funded by DOE, includes investigation of the use or adaptation of techniques for processing minerals for possible application to the clean-up of contaminated land. The Government's Environmental Technology Innovation Scheme has sought proposals for novel techniques to treat organic contaminants in soils, though so far without success. One active area of work, however, is the development of bioremedial techniques in which micro-organisms capable of degrading pollutants are either introduced to the site or stimulated to grow in profusion on the site. Our Thirteenth Report discussed the potential environmental risks of releasing genetically engineered organisms (GEOs) and touched briefly on the need to consider the possible risks from the use of naturally occurring micro-organisms. The Government has subsequently introduced controls over the release of GEOs. We recommend that the Government investigate the potential environmental long-term impact of the use of naturally-occurring micro-organisms in such techniques and consider whether controls are needed.

Landfill Sites

7.61 There are about 4,000 active landfill sites in the UK. Before the introduction of the Control of Pollution Act 1974, there was no requirement in the UK to keep records of landfill sites, so little is known about old sites. It has been reported, however, that there are about 7,500 known completed landfills in England and Wales. About 5% of the active sites account for the disposal of 20% of the 140 million tonnes of controlled waste produced annually in the UK; many of the smaller sites accept less than 20,000 tonnes of waste annually. The main categories of waste disposed of to landfill in the 1980s are given in box 7.8. The operational lifetime of a landfill site is typically 10-20 years.

7.62 The major threat to freshwater quality from landfill is leachate. Rain, liquid or soluble wastes and decomposition products from the wastes percolate through the landfill, to produce leachate which has the potential to pollute surface or groundwater. Leachate from sites containing predominantly domestic waste may be rich in salts, such as sulphate and chloride, and in ammonia; it may also have a high BOD (see box 7.9). Because waste is usually buried (and many landfill sites are former quarries), sources of leachate may be brought close to aquifers, increasing the risk of groundwater pollution. A recent survey of landfill sites showed that about 45% of the sites were located in areas of highly permeable strata and only about 15% of those located over aquifers were lined. Private wells supplying, for example, a few houses or a farm, often draw water from shallow, poorly protected aquifers which may be vulnerable to pollution from sources such as landfills.

7.63 In 1978 DOE published a survey of pollution from 23 landfill sites receiving hazardous waste. Three sites showed no evidence of groundwater pollution; at three others where the natural clay provided a barrier to the migration of pollutants there was little pollution. Minor pollution by oil and chloride was noted at five sites and pollution from organics, including phenols, and from barium and copper to depths of greater than 30 metres was observed at two sites. At other sites more extensive pollution was detected. At Rainham the groundwater contained up to 1% leachate and at Flitwick total organic carbon levels were 570 mg/l and phenols 43 mg/l, the latter being some 86,000 times the maximum admissible concentration subsequently set in the EC drinking water directive (80/778/EEC). Groundwater 250 metres from Coatham Stob contained elevated levels of heavy metals. More recent studies of the impact of landfill on groundwater have shown leachate migrating through the unsaturated zone of Triassic sandstone aquifers in Nottinghamshire from non-containment sites (see box 7.8) at rates of 1-2 metres a year, with little or no attenuation of the principal contaminants. Absence of buffering potential in the sandstone was believed to have inhibited microbial degradation of the acidic leachate.
BOX 7.8 CATEGORIES OF WASTE AND TYPES OF LANDFILL

Three categories of waste — agricultural waste, mining and quarrying waste and controlled waste — account for about 90% of solid waste arisings in the UK (see table below). Operators of landfill sites which receive controlled wastes must be licensed by the waste regulation authorities. Controlled wastes of any kind which are dangerous or difficult to treat or dispose of are referred to as special wastes. In 1990, 90% of controlled wastes in the UK were landfilled, 10% were incinerated. Special waste arisings in the UK were estimated at 2.0–2.5 million tonnes in 1989/90, of which about 70% were deposited in landfills.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Percent of total</th>
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<tbody>
<tr>
<td>Agriculture</td>
<td>37</td>
</tr>
<tr>
<td>Mining &amp; quarrying</td>
<td>34</td>
</tr>
<tr>
<td>Controlled</td>
<td>20</td>
</tr>
<tr>
<td>— Industrial</td>
<td>11%</td>
</tr>
<tr>
<td>— Sewage sludge</td>
<td>4%</td>
</tr>
<tr>
<td>— Household waste</td>
<td>3%</td>
</tr>
<tr>
<td>— Commercial waste</td>
<td>2%</td>
</tr>
<tr>
<td>Dredged spoils</td>
<td>5</td>
</tr>
<tr>
<td>Demolition</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100 (700 million tonnes)</td>
</tr>
</tbody>
</table>

Landfill sites may be divided into two broad categories in their approach to leachate: non-containment and containment sites. Non-containment sites do not attempt to prevent leachate from percolating to the environment; prevention of pollution depends on the attenuation and diluting mechanisms operating both within the waste and in the strata beneath and adjacent to the landfill site.

In containment sites, the aim is to isolate the leachate from the environment either by making use of geological strata of naturally low permeability to prevent leachate percolation, or by lining sites with natural soils such as clay or with synthetic material. Synthetic landfill liners are normally of much lower permeability than clay, or impermeable and therefore able to prevent leachate percolation altogether, but in general they have no adsorptive capacity. Synthetic liners are flexible but are normally protected by clay and sand layers both above and below to prevent puncturing by rocks or refuse. Drainage facilities for leachate collection and monitoring can be incorporated in these protective layers and the leachate can be treated on site. The containment site needs to be capped, on completion of landfilling, by material which is impermeable or of very low permeability, in order to prevent rain or surface water from saturating the wastes. Capping layers are usually clay, contoured to encourage water to run off.

7.64 Although we understand from the Department of the Environment that no groundwater abstraction sources have been permanently lost through leachate pollution, a small number of private supplies have been affected. However, at least one public supply source has had to be closed temporarily to allow additional treatment to be installed to remove pollution reaching the borehole from a landfill site. Little is known, however, about impacts on groundwaters that are not used for water supply. A recent survey of 100 large landfill sites revealed that only about one third were subject to regular monitoring, either for gas production or groundwater contamination. A more comprehensive survey of landfill sites in England is currently being carried out by WRc for DOE but results are not yet available. The Environmental Protection Act 1990 provides the opportunity to require monitoring of leachate production and migration during the active life
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BOX 7.9 THE COMPOSITION OF LEACHATE

Leachate liquors are generated in landfills both as the degradation products of wastes and through the percolation of rain, surface or groundwater through the mass of waste. The composition of waste influences that of leachate. The composition of household waste has changed significantly over the past 50 years, with large increases in paper and cardboard, plastics and putrescible materials, an increase in the metal content and a reduction in inert components such as ashes and glass. Paper and cardboard, and putrescible material represent the largest components of household waste (28% and 26% respectively). Industrial wastes include both solids and liquids and range from readily biodegradable to inert.

In the landfill sites that are common today, anaerobic conditions develop and carbohydrates in the waste decompose to simple sugars and ferment, creating a large BOD and forming carboxylic acids that are the major pollutants in the ensuing leachate (see table below). Acetic acid, accompanied by propionic, butyric and similar acids in lower concentrations, is abundant in leachate derived from fresh refuse. Ammonia, which is released as wastes decompose, is also present. In deep landfills, temperatures of 35 to 40°C can be maintained. Under these conditions, provided the waste is moist enough (about 40% moisture content – the moisture content of household waste is typically 25–35%), carboxylic acids may be broken down, yielding methane and carbon dioxide as landfill gas. The conversion of organic acids to gas will induce a rise in pH and the precipitation of heavy metals. In addition, sulphates will be reduced to sulphides and precipitation of metal sulphides will occur. Thus some of the heavy metals from the waste may be mobilised by the organic acids initially, only to be immobilised later by precipitation.

A review of leachate composition from a variety of landfill types in the UK is currently being conducted on behalf of the DOE and a final report will be produced in 1992. Accumulating evidence suggests that the quality of leachate does not vary much between landfill sites receiving household waste and is indistinguishable from that from sites where hazardous wastes are co-disposed into refuse under properly controlled operations.

<table>
<thead>
<tr>
<th>Range of leachate composition (figures other than pH in mg/litre)</th>
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<tbody>
<tr>
<td>pH</td>
</tr>
<tr>
<td>COD</td>
</tr>
<tr>
<td>BOD</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
</tr>
<tr>
<td>Ammoniacal nitrogen</td>
</tr>
<tr>
<td>Sodium</td>
</tr>
<tr>
<td>Potassium</td>
</tr>
<tr>
<td>Short chain carboxylic acids (as carbon)</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td>Manganese</td>
</tr>
<tr>
<td>Chloride</td>
</tr>
<tr>
<td>Sulphate</td>
</tr>
</tbody>
</table>

Sources: DOE (1991); Parsons (1986); Robinson and Gronow (1991).

of a landfill site and for a specified period after it has closed. We recommend that such monitoring should be required for all landfill sites.

7.65 In our Eleventh Report we discussed the containment of leachate from landfill sites by natural and artificial liners (paragraphs 7.7–7.12) and drew attention to the fact that, although manufacturers suggested that synthetic liners have a life of some 25–30 years, this had not been proved in practice. We recommended (paragraph 7.12) that reliance should never be placed on the long-term containment of leachate which instead should be extracted and processed so that containment failure can not lead to pollution of an aquifer. We are not aware of any evidence emerging in the interim that would lead us to change this recommendation. In its 1991 report on
the draft EC directive on the landfill of waste⁴⁴, the House of Commons Environment Committee recommended 'that the use of synthetic liners should be subject to stringent degradation and transmissivity criteria and quality control and that their design should be subject to approval by the authority controlling the underlying aquifer, so that no risk to the environment or human health is posed.' We support this recommendation.

7.66 Both the Environmental Protection Act 1990 and the proposed EC directive on landfill require management of landfill sites to continue after they have closed and owners to make appropriate financial provision for this. Under the 1990 Act an owner may surrender a licence only when the regulatory authority is satisfied that the site presents no further pollution threat and has issued a completion certificate. Guidance on completion certificates will be issued by the Government by the end of 1992⁴⁵. We recommend that this guidance should emphasise the importance of ensuring that the results of leachate monitoring are taken fully into account in determining whether a pollution threat continues to exist.

7.67 The draft EC directive describes a simple leaching test for hazardous wastes. The test measures the amount of certain substances, such as metals, solvents, pesticides and inorganics, which can be washed out of the waste by water under specified conditions and gives an indication of the likely composition of the leachate. Such tests are an aid to assessing the risks posed by the landfill to surface or groundwater and, hence, to developing management techniques to minimise these risks. The techniques may also be of use in identifying the pollutants which might be leached from contaminated sites during redevelopment and in assessing their potential to reach surface or groundwater.

7.68 Chapter 5 discusses recent proposals from the NRA for protection of groundwater, including policies to restrict landfill activities over aquifers (see paragraphs 5.23–5.25). The implementation of such policies across the UK should help to ensure that new landfill activities pose no risk to groundwaters.

Mining and quarrying

7.69 Whilst mines are active, water is pumped and controlled to prevent flooding. This measure also has the effect of keeping the level of pollutants in the water low. However, when mines close or are abandoned, the flow of water is usually no longer regulated and the mine may flood. In coal mines which contain iron pyrites, flooding can lead to the production of discharges which are rich in dissolved iron salts and highly acidic. When discharged into receiving waters their impact is dramatic. Clear streams turn ochreous, fish die and the river bed becomes coated with insoluble iron salts, killing the macro-invertebrates on which fish feed. A few organisms may, however, thrive under these conditions, such as the bacterium *Leptothrix ochraceae* and the alga *Euglena* which grows as a bright green blanket covering the river bed. Box 7.10 describes the impact of ferruginous discharges on a salmon stream in Scotland and the successful use of settlement and chemical treatment techniques to reduce the acidity and metal content of the discharge⁴⁶. Other recent cases include the pollution of the river Pelela in Wales (see plate 23) and, more recently, pollution of the river Carnon in Cornwall, when the abandoned Wheal Jane tin mine overflowed, discharging millions of gallons of water containing heavy metals, including arsenic, zinc, cadmium and iron (see figure 7.4).

7.70 In general, discharges from abandoned mines are exempt from the need for consents from the regulatory authorities. In the case described in box 7.10, the RPB was able to secure action because of conditions imposed before the mine closed. We recommend that, in view of the serious water pollution threat posed by abandoned mines, the regulatory authorities should review all consents for operational mines to ensure that, where possible, conditions are imposed requiring action to be taken in the event of closure to safeguard water from pollution. The authorities should also review mines which have already been abandoned, identify any which pose a water pollution risk and develop a programme of action to reduce the risk. We consider that the apparent absence of any legal powers to require owners or former operators of abandoned mines...
Figure 7.4 Area of potential groundwater pollution following the Wheal Jane tin mine incident
Some Sources of Pollution

BOX 7.10  FERRUGINOUS DISCHARGES FROM A COAL MINE – THE DALQUHARRAN MINE

The National Coal Board (NCB) was first successfully prosecuted for ferruginous discharges from the Dalquharran mine in March 1974. In anticipation of the risk of future pollution, the Clyde RPB took out a Sheriff's Order when the mine closed down in 1976, requiring that any discharge from the land occupied by the NCB at Dalquharran must not, on neutralisation to pH 7-8, contain more than 60 mg/l of suspended solids. Clyde RPB also installed equipment on the site to monitor the rise of water in the mine following cessation of pumping.

Heavy rain led to an outbreak of acid water from the mine in October 1979, resulting in the most serious pollution incident recorded up to then in Scotland and severely damaging one of the best salmon rivers in Ayrshire. Within 24 hours all fish in the 16 km stretch of the river downstream of the mine to the coast at Girvan were killed. The high levels of iron in the river threatened the closure of Alginate Industries' factory at Girvan and complaints were subsequently received from shipowners in Girvan Harbour claiming that the water was corrosive to ships' hulls. Initially the NCB denied responsibility for the pollution because it had relinquished the lease of the land after closure of the mine. Legal action was taken against the NCB, which was found guilty by the Justiciary Appeal Court. The case made legal history providing the first instance of a guilty verdict against a mine operator after abandonment of a mine.

Following the verdict, remedial action was begun. This involved stopping the ingress of water through surface break-ins (which had caused the water levels in the mine to rise much more rapidly than anticipated), neutralising the acidity and precipitating iron underground by injecting sodium hydroxide and lime into the workings. The flow of water out of the mine was controlled by a dam. Subsequently, water from the upper mine workings, which was relatively unpolluted, was abstracted and discharged into a tributary of the Girvan, reducing the flow of polluted water through the mine. A storage tank was also constructed so that discharge of the reduced volume of ferruginous water took place only when the river was in spate. The river has now been restored to its former condition and the improvement is expected to be maintained.

to prevent pollution is a serious gap in the legislation and we recommend that the Government consider ways of remedying it. We further recommend that, where the owners of the sites are unwilling or unable to carry out work to reduce the risk of pollution, the authorities should seek from the Government the support and the necessary funds to have the work carried out. The charging scheme we propose in chapter 8 could provide a source of funds for this work.

7.71 Coal washeries and preparation plants used to be major sources of pollution but tight control of discharges and the introduction of closed circuit operations has obviated the need for direct discharges to watercourses. Open cast mining is becoming more common. The sites tend to intercept more surface and rain water than shaft mines and generate large temporary spoil tips. The regulatory authorities are consulted before such developments take place so that they have an opportunity to comment on any risks of water pollution. They are also able to control discharges from the workings through their powers to grant consents. However, water quality has been affected through the diversion of rivers and the discharge of mineral solids in this process.

7.72 Mining has left extensive spoil heaps, often in rural areas. Many Nottinghamshire collieries, for example, have deposited spoil directly onto exposed sandstone and limestone aquifers. As surface water percolates through the heaps, its dissolved solids content increases. At a coal tip in Yorkshire, concentrations of pollutants in run-off ranged from 1,300–3,000 mg/l for chloride, 2,600–5,500 mg/l for sulphate, 1,750–3,400 mg/l for sodium, 0.1–5.3 mg/l for iron and 0.1–2.7 mg/l for manganese. In the Derbyshire Peak District the deposition of partially burnt limestone in waste tips has led to highly alkaline leachate which has contaminated surface and groundwater. Spoil from lead mining in Shropshire and Wales has resulted in elevated lead and cadmium levels in drainage water. The poor survival rate of fish in some Welsh waters is attributed to pollution from mine drainage. Reworking old spoil heaps to recover metals is
Chapter 7

becoming more common. Though this reworking uses water, most sites employ closed circuit water flows and other pollution prevention methods, including settling lagoons. There are obvious benefits to be gained from removing the toxic heavy metals from the spoil heaps so long as it can be done without causing pollution.

7.73 China clay quarrying has often led to high levels of suspended solids, causing rivers to silt up, leading to flooding and a deterioration in the rivers' capacity to assimilate other discharges. Rivers have had to be diverted or dredged as a consequence. The imposition of discharge consents with low suspended solids limits and the use of settlement lagoons has had a marked effect in reducing the industry's impact on the aquatic environment. Remedial measures can be expensive. Revenue from the charging scheme proposed in chapter 8 could provide a source of funds to assist. In view of the extremely severe effects that the industry has had on local rivers we recommend that the NRA continue to secure improvements.

Registers of contaminative uses

7.74 When it is brought into force, section 143 of the Environmental Protection Act 1990 will place on local authorities in Great Britain a duty to compile and maintain registers of land which is being or has been put to a 'contaminative use', defined as 'any use of land which may cause it to be contaminated by noxious substances'. Comparable legislation is planned for Northern Ireland. The Government published in 1991 a consultation paper on the proposed registers. The paper outlined a standard method of compiling the registers, defined a wide range of contaminative uses and listed particulars to be included in the registers. It was intended that the duty under the Act would come into force in April 1992 and that the registers would be open to the public from 1993. We note that the Government has recently announced that the legislation will not now come into force in April 1992 and that the period of consultation is to be extended. The Government's announcement stated that it was 'concerned about suggestions that land values would be unfairly blighted because of the perception of the registers.' We regret that the Government has found it necessary to defer introduction of the registers and hope that it will be able to come forward quickly with proposals to enable the purpose of the registers to be fulfilled while allaying any unwarranted fears. The Clyde RPB has commented that the registers will not include details of wastes discharged into former underground mine workings. If this is correct, we recommend that the Government reconsider the position. The NRA is currently producing a list of contaminated sites causing water pollution, from which it will identify priority sites for clean-up. A similar list was produced by the Clyde RPB about three years ago. The NRA intends to use its statutory powers to require owners either to clean up the sites themselves or to pay for this to be done. The data on the registers could also be used to identify areas where the risk of groundwater pollution from contaminated sites is greatest and on which groundwater monitoring strategies should be focused.

Soil quality standards

7.75 The degree of pollution of land is currently defined in terms of its proposed use after redevelopment. Guideline figures, called 'trigger values', which relate the concentrations of substances in the soil to their impact on people or plants, are used to assess a site's suitability for development or to what degree it must be cleaned up. These guideline values do not take any account of the risk to groundwater presented by the site. This point was considered by the House of Commons Environment Committee whose report recommended that a range of quality objectives and standards should be devised which would take into account groundwater or other water systems at risk from pollution. The Government, in its response to the House of Commons report, said that its advice on trigger values largely met this recommendation. Consideration could be given to the need to amend trigger values in vulnerable areas, such as water protection zones, but this was best done on a case-by-case basis, in consultation with the NRA and other interested parties. We consider that this response does not go far enough and recommend that the Government develop appropriate advice on trigger values for sites which may pose a risk to surface or groundwater.
TRANSPORT

Pollution sources

7.76 A report prepared for us by Environment Resources Limited (ERL) surveyed freshwater pollution from certain aspects of transport in the UK. The ERL report identified the main pollutants as: suspended solids from construction works and road drainage; de-icing chemicals, such as glycol from airports; heavy metals, oil and fuel washed off roads and other surfaces; and herbicides used to control weeds along roads and railway tracks. Spillages from accidents were identified as another source of pollution. ERL also surveyed freshwater pollution in the UK deriving from the construction and operation of pipelines. The sources of pollution mentioned above are discussed in the following paragraphs, with the exception of pollution by herbicides which is considered in paragraphs 7.135 et seq. The contribution of nitrogen oxides from vehicle emissions to acidification is referred to in paragraph 6.35.

Road construction

7.77 A study carried out during the construction of the M11 motorway looked at the effects on the river Roding in Essex. The main impact was associated with increased levels of suspended solids which led to blanketing of the stream bed. Major construction projects now require a full environmental impact assessment under the legislation implementing the EC directive on environmental assessment (85/337/EEC). Most projects, regardless of their size, also require planning permission or some other form of authorisation. Chapter 9 includes recommendations to improve the consideration given by planning authorities to environmental matters and to the advice of pollution control authorities.

Drainage

7.78 ERL’s report drew attention to the effects that drainage, especially from roads, can have on freshwater. In urban areas roads normally drain to sewers but, in rural and some urban areas, roads can drain direct to watercourses or to groundwater via soakaways. Drains to sewers often contain gully-pots (box 7.11) equipped with U-bends or similar traps to prevent smells escaping from the sewers. Much of the particulate matter washed from roads, and pollutants such as metals, oil and polyaromatic hydrocarbons from vehicles build up in sediments in the gully-pots. If the gully-pots are not emptied, polluted sediments may be discharged in the first flush of water after heavy rain, either directly into watercourses or indirectly via storm overflows in the sewer system.

7.79 ERL commented that consents for road drainage discharges often contain no quality conditions, or cover relatively few of the likely contaminants. Where quality conditions applied, the pollutants were likely to exceed the consent limits as a result of first flushes from gully-pots. ERL recommended research on road drainage systems to reduce pollution from roads. We support this and recommend that the Government encourage research in this area and provide the stimulus for any promising systems to be developed and tested. ERL also drew attention to the need for drainage systems, such as gully-pots, to be of an adequate size to cope with likely pollutant loads and to be regularly and frequently emptied and maintained. We recommend that the Government review its advice to highway authorities to ensure that these requirements are met.

Road accidents

7.80 ERL’s report discussed water pollution resulting from traffic accidents. Although such pollution is temporary and local, serious accidents can cause major damage. Examples given in ERL’s report include pollution of the river Roding in Essex following an accident involving a lorry carrying insecticide. The river took two years to recover. Improved arrangements have been established between the Fire Service and the NRA for liaison where there is a risk of spilled substances being washed into a watercourse. In the case of chemicals, use of the internationally
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**BOX 7.11 ROAD DRAINAGE**

**Gully-pots**
The gully-pot is a basin underneath the gully grating in the road which collects surface water run-off. Water is discharged from this basin through a U-bend, usually into a sewer. A gully-pot is designed to slow down the flow of water to the sewer and, by virtue of the U-bend, to prevent odours from the sewers reaching pavements. The gully-pot also acts as a settling tank for solids and other substances, including metals, washed off the roads. During rain, the flow of water churns up the sediments and flushes out the gully-pot, with a consequent drop in the quality of the discharge to the sewer and possible contamination of rivers from stormwater outfalls. Cleaning gully-pots at frequent intervals helps to reduce this problem.

**Filter drains**
About half of the road cuttngs in the UK are drained by filter drains, consisting of a ditch filled with gravel or rubble and containing a horizontally laid porous pipe with perforations (known as a French drain) buried some feet below the road surface in the soakaway. As water percolates through the filter medium, suspended solids, metals, polyaromatic hydrocarbons and chemical oxygen demand are removed with an efficiency of about 60-85%. These drains have a life span of 10-20 years, after which time the interstices in the granular filter material become filled with sediments and oily materials.

**Oil interceptors**
Oil interceptors are sometimes installed at sites such as car parks and petrol filling stations where oil pollution of drainage water is a potential problem. Their purpose is to trap the oil in run-off water. They are, however, expensive to install and maintain. If their capacity is exceeded, as it may be during periods of heavy rain, they do not function satisfactorily.

recogised HAZCHEM system for labelling the contents of commercial vehicles is an important aid to identifying substances involved so that the potential risk can be assessed and the most suitable method of dealing with it adopted.

**Airport de-icers**
7.81 The use of large quantities of de-icing agents such as glycol and urea to de-ice aircraft and runways respectively can lead to high concentrations in surface water run-off from airports. Our attention was particularly drawn to this during our visit to Germany. Glycol and urea are both toxic to fish and macro-invertebrates at moderately low concentrations. Both substances have a high BOD and urea gives rise to ammonia. Glycols also interfere with the chemical analysis of a range of other organic substances by commonly used techniques, such as gas chromatography. It is the view of the NRA (a view accepted by the British Airports Authority) that contaminated run-off from airports or airfields requires a discharge consent. Each airport or airfield, however, presents its own problems and in some instances voluntary Codes of Practice have been agreed between the airport operators, including those of military airfields, and the NRA covering the amount of de-icing material used and its application. New formulations which are claimed to be less polluting are under development. We recommend that the water regulatory authorities encourage users to carry out trials of these alternatives and, if successful, require their use in place of more damaging formulations. The authorities should also ensure that run-off is properly collected and, where appropriate, treated before discharge.

**Pipelines**
7.82 ERL's report on freshwater pollution from pipelines identified construction as posing the major risk but concluded that this risk could be reduced by good site management during pipelaying. Nevertheless the Clyde RPB informed us that even in Scotland, where codes of practice have been issued on water pollution control during the construction of pipelines, pollution problems have occurred.

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Some Sources of Pollution

7.83 Although the number of pollution incidents from the operation of pipelines is low, when they occur their impact can be considerable, often because the pollution source is not detected quickly. For example, leakage from the underground pipes of an oil refinery in the Seine valley, near Rouen, France, was discovered in 1990 only after the explosion of inflammable vapours which had accumulated in the cellar of a nearby house. The remedial work following the explosion included extraction of the leaked fuel from the ground which, after several months of pumping, had amounted to some 10 million litres.

7.84 Analyses of pipeline failures have indicated that about 90% of all pipeline failures could be averted by the application of techniques, such as Hazard and Operability Studies, Human Factor Reviews and task and routine checking. Comparisons of pipeline failures in the UK, continental Europe and the USA show a slightly higher failure rate for American oil and gas pipelines than for gas pipelines in the UK. ERL attributes this in part to higher UK standards of design, construction and maintenance.

7.85 Pipelines are sometimes damaged during the laying and maintenance of other nearby service pipes, especially in built-up areas. Guidance developed by the National Joint Utilities Working Group should help to improve liaison between the service utilities and to reduce the frequency of such damage. Age also contributes to the failure rate of pipelines. It is conceivable that the low failure rate of pipelines for oil, gas or chemicals, is due to their comparative youth and that as they get older the failure rate will increase, leading to more pollution from these sources. ERL concluded that this had not yet proved an important source of pollution but that continued vigilance was needed. ERL suggested that frequent monitoring of the condition of pipelines, for example using pressurisation techniques or 'intelligent pigs', and the use of additional pipe protection measures, including clear labelling of their position, would help to reduce the risk of pollution. We endorse these conclusions.

FARMING AND FRESHWATER QUALITY

Introduction

7.86 Since farm land constitutes a major proportion of water catchments, agricultural activities have considerable potential to pollute freshwater. Risks have increased with the trend towards intensification. Livestock produce liquid and solid wastes of high BOD; these as well as effluent from silage have caused severe pollution incidents. Crops require nutrients in a water soluble form, whether provided by manure or artificial fertilisers. Legumes fix nitrogen from the air. Ultimately this can be oxidised in the soil to nitrate and be washed into watercourses or percolate to groundwater. Phosphate, in both organic and inorganic particulate and dissolved forms, can reach watercourses by surface run-off, erosion, drainage and through-flow. Pesticides may leach into groundwater or be transported into surface waters by similar soil processes, and can as a result become concentrated in sediments. Farmers store many materials — oil, wastes, pesticides — which may damage the water environment if spillages or leaks occur. Fish farming, also included in this section, can have a variety of adverse effects on water.

7.87 The need for a positive approach to the solution of environmental problems is becoming increasingly acknowledged in the agricultural sector. For instance, farmers' organisations have shown that they recognise the potential pollution hazards that are associated with agriculture by providing encouragement and support for their members in dealing with environmental problems. The agriculture departments have also developed policies to address some of these issues.

7.88 Of late, interest has been shown in new approaches to the control of agricultural pollution. Amongst these we have noted suggestions for levies on pesticides and on artificial fertilisers. Levies, it is argued, would reduce total usage and would ensure that more care was taken to avoid wasteful or excessive application, thus reducing the likelihood of pollution. In addition the
imposition of such taxes would send an important signal to farmers about the polluting potential of some of their activities. Increased production could no longer be held to excuse potentially polluting practices. Income from the levies could be used to pay for remediating pesticide and fertiliser pollution, thus reinforcing the polluter pays principle. There is, however, doubt as to the effectiveness of such taxes in reducing consumption since demand for both pesticides and artificial fertilisers seems relatively insensitive to their price. We have not compared the merits of product taxes or other market mechanisms with those of traditional regulatory approaches as means of controlling diffuse sources of pollution. The proposals we make in Chapter 8 for a charging scheme would, however, apply to point sources of agricultural effluents in the same way as to other point sources.

Farm wastes

7.89 In 1979, the Royal Commission's Seventh Report, 'Agriculture and Pollution' drew attention to the increasing risks of pollution associated with intensive livestock farming, particularly from animal slurry, silage effluent and yard washings. After rising steadily for many years, the number of recorded surface water pollution incidents associated with farm wastes fell in 1989 (though showing a slight rise again in 1990) but was still nearly double the figure for 1979 (see table 7.5). According to the NRA, 36% of major pollution incidents in England and Wales in 1990 originated from farms. Table 7.6 identifies the main types of incidents in 1988 to 1990. Figures for Scotland are in table 7.7.

Table 7.5
Reported farm pollution incidents in England and Wales

<table>
<thead>
<tr>
<th>Year</th>
<th>Farm Pollution Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>1000</td>
</tr>
<tr>
<td>1981</td>
<td>2000</td>
</tr>
<tr>
<td>1982</td>
<td>3000</td>
</tr>
<tr>
<td>1983</td>
<td>4000</td>
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<td>1986</td>
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<td>1988</td>
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</tr>
<tr>
<td>1989</td>
<td>10000</td>
</tr>
<tr>
<td>1990</td>
<td>12000</td>
</tr>
</tbody>
</table>

Source: NRA/MAFF, Water Pollution from Farm Wastes

7.90 These figures are undoubtedly influenced by factors such as increased public and official interest and weather conditions. The 70% fall in 1989 in the number of silage pollution incidents is generally ascribed to dry weather directly reducing the water content of the plants used in silage-making.

7.91 Recorded figures may substantially underestimate the total incidence of water pollution from farms. Sample surveys of catchments by the NRA and the predecessor water authorities have recorded between 25% and 75% of farms as causing water pollution of some kind at the time of visit and others as being in danger of doing so. Much pollution goes unrecorded in the normal course of events. In a recent report, the NCC has drawn attention to the contribution that farm waste run-off makes to the nutrient enrichment of rivers, including sensitive headwaters, and of lakes and seas. A sample survey by the NCC has identified over 70 Sites of Special Scientific Interest damaged by pollution from farm wastes, often emanating from sources outside the sites. While the recent reduction in recorded incidents is welcome, the problems remain serious and deserve continued attention.
### Table 7.6
Breakdown of farm pollution incidents in 1988, 1989 and 1990

<table>
<thead>
<tr>
<th>Type of incident</th>
<th>1988 No</th>
<th>1988 %</th>
<th>1989 No</th>
<th>1989 %</th>
<th>1990 No</th>
<th>1990 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slurry stores</td>
<td>1032</td>
<td>24.9</td>
<td>758</td>
<td>26.2</td>
<td>632</td>
<td>20.1</td>
</tr>
<tr>
<td>Land run-off</td>
<td>434</td>
<td>10.5</td>
<td>472</td>
<td>16.3</td>
<td>395</td>
<td>12.6</td>
</tr>
<tr>
<td>Treatment system failure</td>
<td>116</td>
<td>2.8</td>
<td>84</td>
<td>2.9</td>
<td>130</td>
<td>4.1</td>
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<tr>
<td>Solid stores</td>
<td>194</td>
<td>4.7</td>
<td>121</td>
<td>4.2</td>
<td>118</td>
<td>3.7</td>
</tr>
<tr>
<td>Yard washings</td>
<td>659</td>
<td>15.9</td>
<td>459</td>
<td>15.9</td>
<td>581</td>
<td>18.5</td>
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<td>Dairy parlour washings</td>
<td>236</td>
<td>5.7</td>
<td>183</td>
<td>6.3</td>
<td>182</td>
<td>5.8</td>
</tr>
<tr>
<td>Silage</td>
<td>815</td>
<td>19.7</td>
<td>245</td>
<td>8.5</td>
<td>470</td>
<td>14.9</td>
</tr>
<tr>
<td>Poultry</td>
<td>64</td>
<td></td>
<td>70</td>
<td></td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Sheep dip</td>
<td>18</td>
<td>0.4</td>
<td>13</td>
<td>0.5</td>
<td></td>
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<tr>
<td>Pesticides</td>
<td>52</td>
<td>1.2</td>
<td>39</td>
<td>1.4</td>
<td>54</td>
<td>1.7</td>
</tr>
<tr>
<td>Vegetable washings</td>
<td>16</td>
<td>0.4</td>
<td>29</td>
<td>1.0</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Oil spillages</td>
<td>93</td>
<td>2.2</td>
<td>81</td>
<td>2.9</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Fish farms</td>
<td>10</td>
<td>0.2</td>
<td>46</td>
<td>1.6</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>402</td>
<td>9.7</td>
<td>289</td>
<td>10.0</td>
<td>414</td>
<td>13.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4141</strong></td>
<td>100%</td>
<td><strong>2889</strong></td>
<td>100%</td>
<td><strong>3147</strong></td>
<td>100%</td>
</tr>
</tbody>
</table>

(Source: NRA/MAFF, Reports for these years)

### Table 7.7
Reported farm pollution incidents in Scotland in 1988, 1989 and 1990

<table>
<thead>
<tr>
<th>Source of Pollution</th>
<th>1988 No</th>
<th>1988 %</th>
<th>1989 No</th>
<th>1989 %</th>
<th>1990 No</th>
<th>1990 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle housing and yard</td>
<td>27</td>
<td>4.7</td>
<td>21</td>
<td>4.5</td>
<td>23</td>
<td>4.3</td>
</tr>
<tr>
<td>Piggery and yard</td>
<td>8</td>
<td>1.4</td>
<td>22</td>
<td>4.8</td>
<td>10</td>
<td>1.9</td>
</tr>
<tr>
<td>Poultry house and yard</td>
<td>15</td>
<td>2.6</td>
<td>8</td>
<td>1.7</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>Slurry store</td>
<td>74</td>
<td>12.9</td>
<td>66</td>
<td>14.3</td>
<td>57</td>
<td>10.7</td>
</tr>
<tr>
<td>Dungstead</td>
<td>31</td>
<td>5.4</td>
<td>17</td>
<td>3.7</td>
<td>12</td>
<td>2.2</td>
</tr>
<tr>
<td>Dairy premises and milk parlour</td>
<td>25</td>
<td>4.4</td>
<td>25</td>
<td>5.4</td>
<td>22</td>
<td>4.1</td>
</tr>
<tr>
<td>Milk bottling plant</td>
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<td>—</td>
<td>3</td>
<td>0.6</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sheep dipper unit</td>
<td>8</td>
<td>1.4</td>
<td>13</td>
<td>2.8</td>
<td>18</td>
<td>3.4</td>
</tr>
<tr>
<td>Vegetable washing unit</td>
<td>5</td>
<td>0.9</td>
<td>8</td>
<td>1.7</td>
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<td>1.1</td>
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<tr>
<td>Silage</td>
<td>282</td>
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<td>173</td>
<td>37.4</td>
<td>281</td>
<td>52.5</td>
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<td>Chemical fertiliser store</td>
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<td>0.3</td>
<td>3</td>
<td>0.6</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Chemical spraying/fertiliser spreading equipment</td>
<td>17</td>
<td>3.0</td>
<td>14</td>
<td>3.0</td>
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<td>1.5</td>
</tr>
<tr>
<td>Run-off from land</td>
<td>33</td>
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<td>36</td>
<td>7.8</td>
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<td>Waste treatment system</td>
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<td>—</td>
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<tr>
<td>Farm tip</td>
<td>9</td>
<td>1.6</td>
<td>9</td>
<td>1.9</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>Oil</td>
<td>16</td>
<td>2.8</td>
<td>18</td>
<td>3.9</td>
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<td>Stream cleaning</td>
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<tr>
<td>Miscellaneous</td>
<td>12</td>
<td>2.1</td>
<td>20</td>
<td>4.3</td>
<td>33</td>
<td>6.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>572</strong></td>
<td>100%</td>
<td><strong>462</strong></td>
<td>100%</td>
<td><strong>535</strong></td>
<td>100%</td>
</tr>
</tbody>
</table>

(Source: Scottish Farm Waste Liaison Group)
Livestock slurries

7.92 Livestock wastes are generally disposed of on farm land as part of normal farming practice (though in a few cases small treatment plants have been installed on farms, normally to avoid odour problems or because of adjacent housing). The availability of manufactured, bought-in feed and of mechanised slurry handling systems has removed two constraints on animal numbers. Farmers have consequently been able to increase their herds to sizes that produce manure in greater volume than can be spread on the land without undue risk of pollution. Research on a Welsh catchment showed the majority of land to be unsuitable for slurry application at any time other than the dry summer months. Significant rainfall led to high ammonia and low dissolved oxygen concentrations in local streams, probably by washing farm wastes off yard surfaces and land to which slurry had been applied.

In addition, information supplied by MAFF suggests that intensive pig and poultry units will often be stocked at a level which makes it difficult to dispose of their wastes on land directly associated with the enterprise.

7.93 The BOD of slurry averages 100 times that of untreated domestic sewage (largely because of latter is diluted by bath and other domestic water). It is therefore a powerful depleter of the dissolved oxygen in surface waters, and relatively small quantities lead to the death of fish and other aquatic wildlife. Animal slurries also have a high ammonia content. Ammonia is readily soluble in water and highly toxic to fish.

7.94 As table 7.6 shows, in 1990 about 12% of recorded farm pollution incidents were caused by slurry running off land; a further 20% involved slurry stores. MAFF acknowledges that only a small proportion of farmers invest in pollution control systems each year at present, while the NRA's surveys have identified the majority of farmers as needing to invest in such systems.

7.95 In the last few years, the Government has made some important changes. Compliance with a Code of Good Agricultural Practice no longer provides a defence against prosecution for a farmer who has polluted a watercourse (see box 7.12). Regulations have been introduced controlling the construction of new slurry, silage and agricultural fuel oil stores to reduce the risks of pollution. In addition, a substantially revised Code of Good Agricultural Practice for the Prevention of Water was published in 1991 and made freely available to farmers. It gives farmers practical guidance on how to plan their disposal of slurry and other organic wastes. New Codes of Good Agricultural Practice for the Protection of Air and Soil are in preparation and the Scottish Office Agriculture and Fisheries Department has produced a separate Code of Practice on the Prevention of Environmental Pollution from Agricultural Activity. Changes have also been made in grant aid and we discuss these in paragraph 7.104.

**BOX 7.12 GOOD AGRICULTURAL PRACTICE FOR THE PROTECTION OF WATER**

Present legislation provides for the Secretary of State and the Minister of Agriculture, acting jointly, to approve a Code of Good Agricultural Practice. There are similar provisions in Scottish law. The code may give practical guidance on activities liable to affect water, and promote ways of avoiding or minimising water pollution.

A new Code for the protection of water was published by the Agriculture Departments of England and Wales in July 1991. It describes the main risks of water pollution from agricultural sources and defines Good Agricultural Practice in a way intended to minimise the likelihood of water pollution while enabling economic agricultural practice to continue.

Compliance with the code is no longer a defence against prosecution for polluting water as it was until 1989. Contravention of the code does not give rise to criminal or civil liability but the NRA must take contraventions or likely contraventions into account before issuing a notice prohibiting a discharge or serving an improvement notice under the regulations on silage and slurry stores and oil facilities.
7.96 These moves are welcome; they do not, however, address the fundamental imbalance that can exist between the scale of livestock units and the capacity of nearby land to take the wastes produced. When these are out of balance, the best constructed stores and the most conscientious farming practices may not be sufficient to reduce to acceptable levels the risks of serious water pollution.

7.97 The approach to be taken to this imbalance should, in our view, be consistent with the industrial nature of intensive livestock production. Units which do not have access to sufficient land suitable for safe disposal should be required to provide or arrange treatment for excess animal wastes. Several treatment processes exist; others are the subject of research. Possible methods include aerobic or anaerobic digestion, although care will still be needed to avoid water pollution in disposing of the resulting products. In some cases incineration may be necessary. Appropriately skilled operators will be required for such plant. Prototype plant is undoubtedly expensive but there are grounds for belief that, with further development and the establishment of co-operative ventures, economically viable units could be designed and operated in this country as they are abroad.

7.98 Environmental impact assessment is now required for certain types of agricultural development, for example, poultry and pig-rearing projects which require planning permission and which are likely to have significant effects on the environment. Although this requirement is welcome, neither the assessment process nor the planning system itself provides a satisfactory way of controlling the disposal of farm wastes. First, the guidance on the size of development which is likely to have significant environmental effects requires review (see paragraph 9.17). Secondly, not all developments which may have waste disposal problems require planning permission. Thirdly, the planning system operates in relation to proposed developments. It offers little scope to control existing livestock units. Fourthly, once planning permission is granted, changes in environmental requirements cannot easily be introduced. In addition, not all the planning authorities yet have the expertise in farming practices, treatment processes, soil structure, drainage or topography to make informed decisions on the acceptability of new proposals. Consultation procedures exist but they do not necessarily result in adequate safeguards.

7.99 We therefore recommend that operators of intensive livestock units above a specified size should be subject to an authorisation system to be operated by the agriculture departments. Authorisation would be required for new and existing units and should be granted only where the operator has adequate storage and disposal arrangements, taking account of the size of the unit, the scope for spreading the wastes on surrounding land without risk of pollution and any arrangements for treatment or other methods of disposal made by the operator. Advice on disposal techniques should be provided by ADAS. We recommend that, in considering applications for authorisation, the agriculture departments should act in consultation with the NRA/RPAs but should also take account of all risks of nuisance and environmental pollution, not only those relating to water. We recommend that the Government should periodically review the workings of the authorisation scheme and consider reducing the size qualification if problems still occur with smaller units.

7.100 Disposal of yard and parlour washings can also be difficult. These washings are substantial in volume and account for about 20% of farm pollution incidents. We do not underestimate the difficulties of dealing with them but would emphasise that no industrial enterprise would be permitted to produce large volumes of polluting effluent without a satisfactory means of disposal. Agricultural units should not expect to be treated differently.

7.101 The NRA has proposed the development of a national strategy for agricultural waste management, to be implemented through individual farm plans. It envisages that the adoption of such plans should be a pre-requisite for grant support for pollution prevention measures. We support this proposal and we see it as a constructive development of the existing consultation procedure which normally accompanies a request for grant aid. We recommend that such a plan, making proper provision for the utilisation and disposal of wastes (including yard and parlour washings), should be a requirement of the authorisation scheme proposed above for large
livestock farms. Although smaller units would not be subject to our proposed authorisation, we consider that for them, too, the preparation of a farm plan, with the guidance of experts in ADAS and the regulatory authorities would help to identify the main risks.

7.102 A system of waste management plans and authorisations is likely to expose local difficulties in disposing of farm wastes and encourage alternative utilisation and disposal routes. These might include both the safe transport of slurry and its beneficial use. We were impressed by the constructive attitude of Danish agriculture where slurry is looked at less as a waste disposal problem than as a potential resource, and ways are sought of using it beneficially. One of our members inspected Danish schemes for converting slurry into gas (which can be used for local heating) and fertiliser or sanitised slurry, as well as a liquid effluent suitable for application to land during a permitted period. We recommend that the Government should take the lead in investigating with farming interests the scope for encouraging such technology, and should make financial support available for suitable projects.

7.103 We also consider that the authorisation system advocated above should be complemented by flexible powers enabling the pollution control authorities to require, at the expense of the potential polluter, preventive action to reduce the risk of water pollution. We recommend in chapter 9 that powers, modelled on the provisions of the Health and Safety at Work Act, which enable preventive action to be required where a risk to health or safety exists, should be given to the water regulatory authorities.

7.104 Although we consider that an authorisation scheme for intensive livestock units has a vital part to play in controlling the way they dispose of wastes, it will not remove the need for advice and, in appropriate cases, grant aid to improve waste disposal systems. MAFF told us that the Agricultural Development Advisory Service (ADAS) offers free initial advice on pollution prevention matters but detailed technical advice is on a fee-paying basis. The Government has said there would be 5,000 free farm visits by ADAS in 1991. In view of the number of water pollution incidents recorded we doubt whether this is enough. We recommend that the Government should ensure that ADAS actively seeks opportunities to offer advice on pollution control, free of charge wherever possible, and that it has sufficient resources to do so. The Farm and Conservation Grants Scheme offers up to 50% of the cost of new or improved waste management systems. Over £30 million was paid in grants in the first 2½ years of this scheme. The previous scheme offered 30% in lowland areas but 60% in Less Favoured Areas. The Government should ensure that the scheme provides an adequate incentive to improve waste management systems in Less Favoured Areas since these contain many vulnerable waters. It should also ensure that the types of treatment plant referred to in paragraph 7.97 above would be eligible for grant aid when proposed by co-operatives, which are currently not eligible. Joint ADAS/NRA advisory campaigns have shown some success in reducing pollution incidents. We welcome this collaborative approach, linking advice and education with a firm policy of prosecuting the small minority of farmers who carelessly or irresponsibly cause serious pollution incidents.

Silage

7.105 Silage effluent is one of the most potentially polluting farm wastes. It is about 200 times stronger in BOD than raw domestic sewage and about twice as strong as slurry. Care must therefore be taken over the construction of silos, effluent collection systems and storage tanks and over the disposal of effluent. A reduction in the number of inadequately constructed silos is to be expected as the new regulations start to bite. Reductions in the volume of effluent, which can be obtained by reducing the moisture content of the crops, are also important in minimising risks in containment and disposal. Farmers are advised to wilt the silage crop by leaving it in the field to dry for a period after cutting. Even a wilt of 3 or 4 hours can be beneficial, but the scope for this depends on favourable weather conditions. A recent trend towards harvesting silage directly into large wrapped and sealed bales may help to reduce problems, provided they do not leak, but care is needed when opening them to ensure that liquor does not spill into drains or watercourses. Moisture content is not the only factor involved in producing silage effluent and we welcome the research in progress which aims to understand all the mechanisms involved.
BOX 7.13 SILAGE

Silage is made by storing grass or other suitable crop under anaerobic conditions, for example compressed and covered by or wrapped in plastic, or in an enclosed tower where the air supply is restricted. Under these conditions the crop ferments, sometimes assisted by chemical additives, producing organic acids which preserve the material against further microbial breakdown. The resulting silage has a nutritional value similar to that of the fresh crop. The fermentation process produces a liquor almost as soon as silage making starts and maximum production occurs within a few days. The liquor, whose volume is determined by the moisture content of the silage, has a very high BOD, ranging from 12,000 to 80,000 mg/litre and is also very acidic. It can damage silos and effluent storage tanks and can scorch crops or grassland if applied indiscriminately.

Silage has largely replaced hay as the favoured means of conserving grass to supplement winter rations for livestock. Its main advantages are that the process is less vulnerable to bad weather, and earlier cutting is possible, allowing quicker regrowth of the grass. Silage production in England and Wales has increased from about 5/t million tonnes in 1970 to over 30 million tonnes in 1989, a slight reduction on the figure for 1988.

Fish farming

7.106 The controlled rearing of fish is carried out in both salt and freshwater; only the latter is relevant to this report. Production, for restocking waterways and lakes, supplying other fish farms or as food, is concentrated predominately on Atlantic salmon parr and trout, especially rainbow trout. There is also some production of coarse fish for restocking. Notwithstanding a decline in 1990, the industry has grown rapidly in the last two decades. Production of salmon and trout grew from under 1,000 tonnes in the early 1970s to over 16,000 tonnes of trout and 18,000 tonnes of salmon in 1988. Farmed freshwater fish are reared in natural or excavated ponds, in freshwater tanks or raceways on land adjacent to rivers, or in cages of netting suspended in lakes, freshwater lochs, or reservoirs.

7.107 Fish farms require a large, constant supply of high quality water. As the industry has expanded, so has concern about its effects on the environment. The principle issues include the effects and treatment of waste effluents from farms; the use of prophylactics and veterinary products to control disease among farmed fish; the threat of genetic admixture in populations of wild fish from the escape of farmed fish; the consequences for wildlife of predator control on farms; and the over-abstraction of water by land-based farms. The House of Commons Select Committee on Agriculture, the NCC, and WRc have published reports discussing these and other issues. The industry is itself aware of them and discussed with us during our study the steps it was taking to investigate and find solutions to the problems. One earlier criticism in the Commission's Seventh Report — the absence of planning control over fish-farming development — has recently been answered by the Government. Full planning applications will now be required, except for certain minor works of which the planning authority must receive prior notification.

Fish farm waste and nutrients

7.108 The waste from fish farms and cages may contain large amounts of nutrient-rich, organic matter. Such nutrients may stimulate plant growth while solids can reduce light penetration or smother bottom-dwelling flora and fauna. In some circumstances, domination by a few, pollution-tolerant species can ensue and, at worst, waters may become anaerobic and devoid of higher organisms. This has occurred beneath some cages. The enrichment of lakes with organic and inorganic nutrients can increase BOD. Decreases in ambient levels of dissolved oxygen have been linked with disease and mortalities in several fish farming operations. In some parts of Scotland the additional effects of afforestation have produced a combined nutrient loading which has greatly accelerated the rate of enrichment of naturally oligotrophic waters.
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7.109 The control of waste effluents from enclosed, land-based farms is considerably easier than that from cages and several waste treatment systems are commercially available. Some experimental attempts have been made to remove wastes produced by caged stock and new cage designs are claimed to prevent or reduce the release of wastes into the environment. More research and development is still required in order to improve waste removal technology. Research is being carried out into the use of the waste solids from pond farms and cages as a raw material for further composting or creating soil conditioner. Methods continue to be developed to improve food conversion ratios and to balance supply against uptake of food, in order to decrease the environmental impact of surpluses.

7.110 The aim must be to reduce wastes from cages and land-based farms to a minimum. A clearer understanding of the environmental dispersion and fate of wastes from fish farms would aid development of appropriate management strategies. These could be assisted by better computer modelling of expected nutrient outputs from cages and hence their likely environmental effects but must be combined with improved methods of monitoring, and of disposing of discharges from cage farms. At least until much better disposal methods have been developed, we recommend that cages should be sited in a manner and position consistent with the efficient dispersal of wastes and should not be permitted where this cannot be satisfactorily achieved, for example, in deep, still waters where the risk of deoxygenation of the hypolimnion is high. In addition, the pollution control authorities should ensure that they use to the full their powers to limit discharges from fish farms so as to prevent adverse effects, for example, by requiring waste streams from river based fish farms to be treated before discharge in order to maintain the quality of the receiving water.

Effects of veterinary chemicals

7.111 Farmed fish are reared at a high stocking density and are susceptible to a wide range of diseases. Some antibiotics, such as oxolinic acid and oxytetracycline, may be incorporated into feed to treat fish but little is known about the environmental effects of this practice. The use of antibiotics in fish culture is controlled by the Medicines Acts 1968 and 1971 which permit them to be used only under veterinary prescription to control certain bacterial infections: they may not be used as prophylactic treatments. The concentration of antibiotics in effluents from fish farms is very low; for example in the case of oxolinic acid the minimum dilution in the effluent is likely to be about 1:50,000,000. Loss of antibiotics will be variable but research in Scandinavia has indicated that some 70-80% of the oxytetracycline treatment enters the environment, where it is frequently taken up in sediments. Thence it may gradually leach into the water column over a period of months. This raises the prospect of adverse changes being induced in the composition of the aquatic microbial population in the vicinity of fish farms, particular concern attaching to the acquisition and spread of antibiotic resistance. Increased numbers of antibiotic resistant bacteria have indeed been found where antibiotics have been used on rainbow trout farms. The possibility that antibiotic resistance might be transferable from such bacteria to pathogenic bacteria of veterinary or clinical importance remains one of the main concerns regarding the use of antibiotics in aquaculture. We recommend that, in addition to the routine assessment of environmental safety which forms part of the licensing procedure for veterinary medicines, their long-term fate and effects in the aquatic environment should be more extensively studied.

7.112 Various chemicals are used in fish farming as disinfectants and as veterinary medicines. The substances used include malachite green, which has been suspected as having teratogenic effects at high concentrations. Some countries have proposed to ban it but, so far as MAFF is aware, have not proceeded. The few data on its effects, particularly outside the farm environment, do not allow any general conclusion to be reached and there is a clear need for research into the fate and effects of malachite green in the freshwater environment. Following the ban in 1987 on the use of tributyl-tin compounds, net-fouling (the growth of algae on fishing nets) is now controlled by the use of copper based substances or by washing. In addition to therapeutic agents, vitamins are used to enhance growth, and pigments to colour fish flesh. The vitamins may possibly act as micro-nutrients and enhance the growth of algae. The pigment canthaxanthin is used in the UK to produce pink flesh in farmed salmon and to a lesser extent trout. The
Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment has been unable to set an acceptable daily intake for canthaxanthin, which accumulates in the human eye and after long term exposure can impair visual function. In the UK, the use of canthaxanthin has decreased, being largely replaced by synthetic astaxanthin. There is no evidence that astaxanthin accumulates in the eye but little is known about its environmental fate.

7.113 We recommend that consent conditions should be set for antibiotics and other biologically active chemicals in effluents from fish farms. Further research may be needed to establish standards to protect the environment and public health.

Disease control and effects on wild aquatic populations

7.114 If infected farmed fish escape to the wild they may carry disease to wild fish populations. The major threat appears to be from the introduction of exotic pathogens from imported fish or eggs. The introduction to the UK of the signal crayfish for hobby farming brought with it a fungal disease, crayfish plague, which has eliminated native crayfish from at least ten rivers and one enclosed site in the UK67. Similarly, imported fish have been suggested as the most likely source of spring viraemia of carp (SVC). This disease, which can result in significant mortalities in affected carp stocks, is endemic in several countries in mainland Europe, though not in Great Britain. The greatest risk of spreading the disease is by the movement of infected stock. Before 1988, only four cases of SVC had been confirmed in Great Britain but more widespread outbreaks occurred in that year and there have been further outbreaks since then68. To minimise the transmission of disease, the highest standards of hygiene are essential at all stages of the fish rearing process and in the movement of fish stocks. There is also a need to improve understanding of both the transfer of disease between farmed and wild stocks (and vice versa) and the survival time of pathogens in water.

7.115 Escaping farmed fish may carry other characteristics to the wild population. Genetic differences have been demonstrated between populations of wild fish in different river systems and even in different stretches of river. These genetic differences may be important adaptations to local conditions, but there is no doubt that the transfer of fish from catchment to catchment, often to ensure the availability of stocks for anglers, has altered the natural biogeography and probably affected the ecology of many rivers in the UK. Interbreeding with farmed fish could also reduce the fitness of wild fish populations. There appears to be scope for fuller understanding of the genetic transfers between farmed and wild fish stocks.

7.116 The fish farming industry is aware of its effects on the environment and is participating in and supporting research to address them. However, measures to control pollution from fish farms have not in general kept pace with the growth of the industry. The Commission’s Seventh Report argued that fish farming should be seen as another aspect of intensive livestock farming. We recommend above that operators of large intensive stock units should be subject to an authorisation system which would require them to demonstrate that they had adequate arrangements for the disposal of wastes. We consider that this concept should extend to fish farming. Fish farming would thus be subject to a range of controls, covering planning issues, water abstraction (but for Scotland see paragraph 117), use of veterinary medicines and waste disposal, which are designed to ensure its full environmental acceptability.

River flow depletion

7.117 Land-based fish farms may be supplied by borehole or rely on river abstraction. In England and Wales, piecemeal exploitation has sometimes led to stretches of river being bypassed and drying up, leap-frogging of fish farms further and further upstream, and adverse effects on the quality of water for other purposes. In Scotland, too, abstraction has left stretches of river dry in summer. In some localities abstraction of water by fish farms has so depleted the volume of water that the residual flow is insufficient to dilute the waste effluent. Nutrient enrichment and gross organic pollution of the watercourse have resulted, leading to changes in weed growth and an increase in pollution tolerant organisms69. Changes made to English and
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Welsh law on water abstraction should prevent such problems from arising in future. For the present level of over-abstraction to be brought under control would, however, almost certainly require the payment of compensation to the abstractors. In Scotland, most abstractions are not subject to licensing. We return to this subject in chapter 9 where we recommend that the situation should be re-examined with a view to providing protection for Scottish water resources.

Watercress production

7.118 Cress farming in the UK is a relatively small industry with an annual turnover of about £9 million but makes extensive use of freshwater. Concern about water quality downstream from watercress beds has been expressed by angling interests, mainly because of occasional high concentrations of silt caused when the cress beds are cleaned. In addition, the absence of freshwater shrimps from many streams just below cress beds has been noted. These shrimps form a major element in the diet of trout, which thrive in the type of chalk stream favoured by the watercress industry. It is believed that the shrimps have not been killed but are avoiding waters tainted by the insecticides used to avert or control insect attack. Zinc sulphate, used for this purpose and at one time suspected of blame for the disappearance of the shrimps, is now thought less likely to be responsible. The NRA's Southern Region has advised that there is a need to monitor the watercress industry and to establish consents to control pollution from it. We understand that action is in hand on these measures and we recommend that the authorities ensure speedy and effective action on both fronts.

NITRATE

Introduction

7.119 The Commission's Seventh Report discussed in detail the contribution of nitrogen fertilisers to the increasing levels of nitrate found in freshwater. The physical and chemical processes involved and the reasons for concern are fully described in that report and in others subsequently, notably by the Royal Society, the Department of the Environment, and the House of Lords Select Committee on the European Communities. We refer readers to these sources for a full treatment of the subject. In this section we restrict ourselves to a few supplementary comments.

Nitrate levels and current agricultural practice

7.120 There are three main routes by which nitrate reaches water — run-off or leaching from agricultural land, sewage and animal waste effluents, and precipitation from the atmosphere. Groundwater is mainly affected by leaching from agricultural land whilst rivers receive nitrate from all three sources. Changes in agricultural practice over the last 40–50 years, such as the ploughing-up of grassland, new crops and increased fertiliser use, are generally thought to be major causes of increases in nitrate levels in water but airborne inputs of nitrogen oxides are now increasing.

Nitrate in the water environment

7.121 The main concerns arising from the concentration of nitrate in freshwater relate to its properties as a plant nutrient and its possible impact on health as a contaminant in drinking water. We have seen little evidence that elevated levels of nitrate alone have major effects on the freshwater environment. Nutrient enrichment is the principal effect and we discuss this more extensively in chapter 6.

7.122 In the Norfolk Broads, however, we were shown reed die-back attributed to elevated nitrate levels. Excessive nitrate encourages the growth of stems at the expense of root systems. The most significant effect is on the floating form of reed ('hover') whose stability is reduced and vulnerability to mechanical damage increased. In turn, river banks are less well protected and their erosion is aggravated by wash from boats. This series of effects is regrettable for aesthetic and ecological reasons and also has economic implications.
Some Sources of Pollution

7.123 The appearance for a number of years of local algal blooms in parts of the North Sea has increased concern about the input of nutrients to the seas. At the 1987 North Sea Conference, the Government agreed to the aim of achieving a substantial reduction (of the order of 50%) between 1985 and 1995 in inputs of phosphorus and nitrogen to areas where those inputs are likely to cause pollution. Although a reduction in atmospheric inputs will help to achieve that aim, significant reductions in riverine sources will also be required.

Health aspects

7.124 The Royal Commission's Seventh Report commented on the two main health issues associated with nitrate, namely the methaemoglobinaemia (blue baby syndrome) that may affect infants in the first few months of life, and a possible link with the aetiology of cancer.

7.125 A substantial intake of nitrate can contribute to the development of methaemoglobinaemia in infants under six months. Other factors, such as bacterial contamination and concurrent illness such as gastroenteritis are also important. The disease is extremely rare in the UK: the last confirmed reported case directly attributable to nitrate in drinking water was in 1972.

7.126 The Seventh Report also reviewed the evidence that nitrate may be implicated in some forms of human cancer, especially gastric cancer, through the formation of metabolites known as N-nitroso compounds, such as N-nitrosamines and nitrosamides. The suggestion arose because many substances in this class cause cancer in animals under laboratory conditions. The Report found no evidence that unambiguously associates nitrates and N-nitroso compounds in human tissues or body fluids with carcinoma of any organ in man. In 1984, the Joint Committee on Medical Aspects of Water Quality noted that 'the incidence of gastric cancer is relatively low in those regions where nitrate concentrations are relatively high; and the overall incidence of gastric cancer in England and Wales has continued to fall over the last 30 years, despite the increase in water concentrations over that period'73. In 1989, Sir Donald Acheson, the then Chief Medical Officer of the Department of Health, stated: 'There is no epidemiological evidence that the concentrations of nitrate in water in the United Kingdom, or the levels of exposure to nitrate from all sources, are actually associated with an increased risk of cancer. The epidemiological evidence shows that nitrate cannot be having a major effect on cancer in the general population in the UK. Nevertheless, the inherent limitations of such evidence means that we cannot absolutely exclude a small risk'74. A report published in 1988 by the European Chemical Industry Ecology and Toxicology Centre reached conclusions consistent with those expressed in this and the previous paragraph.75.

7.127 The statutory maximum admissible concentration for nitrate in drinking water (50 mg per litre as nitrate), which is set in the EC drinking water directive agreed in 1980, was apparently based on a standard set by the World Health Organisation (WHO) in 1970 to protect infants from methaemoglobinaemia. This recommended that water suppliers should where possible provide water with a nitrate concentration of less than 50 mg per litre, but that a supply in the range 50–100 mg per litre was acceptable, provided community physicians in the area concerned were warned to look out for the possible occurrence of methaemoglobinaemia in infants. In 1984 WHO issued revised guidelines for nitrate which recommended 10 mg per litre as nitrogen, (equivalent to 44.3 mg of nitrate per litre) as a figure above which health authorities should be consulted for advice. In contrast, the EC limit is an absolute one to be met at all times. We have not been convinced that this strict limit is needed to safeguard health in the UK or any other country with a satisfactory public water supply system. We regret that the EC limit has created anxiety in the minds of consumers whose supplies are known to be marginally in breach of the limit, has removed from use several water sources which were regarded as secure, possibly diverted resources and attention from more deserving objectives, and created some environmental problems in disposing of nitrate removed from supplies.

7.128 As opportunities have begun to diminish for the water industry to blend high nitrate water with low to meet the mandatory limit of 50 mg/l, other methods have been developed for removing nitrate from water. Most of these are based on either ion exchange or biological denitrification following the addition of a carbon source, usually methanol. Ion exchange is
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currently the method of choice for groundwater treatment, although it has the disadvantage of producing a concentrated saline effluent containing nitrate which presents a disposal problem. There is also some concern that elevated chloride levels resulting from this treatment could give rise to corrosion in supply pipes.

7.129 About 99% of the UK population receives mains water supply. For the small proportion still dependent on private supplies, concern has been expressed that shallow wells can be contaminated by nitrate from farmland, or by sewage leaking from adjacent cesspits. Local authorities are responsible for monitoring private supplies but there are as yet no comprehensive data on nitrate levels found in them. However, a 1988 survey of 720 private supplies in Scotland found 10% to have concentrations exceeding the limit of 50 mg/l set by the EC drinking water directive. The Government has now made Regulations which require all private supplies to be identified, monitored (for nitrate inter alia), and classified76. We anticipate that this survey will provide a thorough assessment of the quality of private supplies and provide a firm basis for proposals for their protection.

Control over nitrate levels

7.130 Nitrate’s role in the nutrient enrichment of fresh and eventually sea waters, coupled with the EC nitrate limits for drinking water, make it unacceptable for levels of nitrate in freshwaters to continue to increase. Action is needed to stop the rising trend and, preferably, secure a reduction in the worst affected waterbodies.

7.131 For this reason we welcome the recent agreement in the EC to a directive on the protection of fresh, coastal and marine waters against pollution caused by nitrates from diffuse sources77. This requires member states to designate both surface and groundwater zones vulnerable to nitrate pollution (those likely either to breach the limit in the drinking water directive or to be eutrophic) and to introduce action programmes designed to reduce the pollution. Initially the action programmes will limit the amounts of fertiliser and manure which may be applied to land and will require farmers to comply with good agricultural practice in reducing nitrate pollution. There is provision for further measures to be introduced at the discretion of member states if they believe the first tranche of controls will be ineffective.

7.132 The Government has already introduced a Nitrate Sensitive Areas (NSA) scheme, designed mainly to test the effectiveness of changes in farming practice intended to reduce nitrate leaching. The scheme also provides for compensation to be paid in areas where restrictions, for example on the use of fertiliser, exceed the requirements of good agricultural practice.

7.133 The Government has also taken complementary steps, including revision of the Code of Good Agricultural Practice for the Protection of Water, to encourage farmers generally to adopt a range of practices designed to make the most efficient use of fertiliser, especially nitrate. In particular, emphasis is placed on the desirability of reducing to a minimum the risk of leaching and avoiding point source pollution of surface waters.

7.134 We welcome these measures and consider it important that maximum benefit is obtained from them in implementing the new directive. It will be a major task to designate the vulnerable zones since they are likely to be extensive. Meanwhile the outcome of the NSA pilot scheme is being assessed; its interim results should be taken into account where practicable in order not to delay wider action. If the scheme demonstrates potential to reduce nitrate pollution cost-effectively, its lessons should be rapidly applied, for example in implementing the further measures envisaged in the nitrate directive.

PESTICIDES AND THE CONTAMINATION OF FRESHWATER

The role of pesticides

7.135 The crop yields achieved by modern agriculture have enabled farmers to satisfy public demand for copious and secure supplies of cheap food. This would be impossible without the use of modern technology including the use of pesticides to control fungal diseases, weed infestation
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and insect or other pests. Pesticides also have a role in public health, for example, in reducing the risks of infection in hospitals and restaurants, and in controlling rat populations in sewers. They have also improved the efficiency of weed control in public open spaces, on roadsides and on railway tracks.

7.136 In recent decades, pesticides have been developed to be more specific in action and safer for both their users and the environment. Nevertheless, their safe storage, optimal use and safe disposal remain of crucial importance. Many chemicals which persist in the environment have now been withdrawn from use (at least in the developed world) and their successors are often designed to degrade fairly rapidly in soil or plants. Traces of older pesticides, such as organochlorine insecticides, continue to be found in water, and the newer compounds retain the potential to harm both human health and the environment if they are mishandled.

<table>
<thead>
<tr>
<th>BOX 7.14 PESTICIDES</th>
</tr>
</thead>
<tbody>
<tr>
<td>The term ‘pesticide’ is used in this report to include the wide variety of chemicals used in agriculture and elsewhere to kill or otherwise control weeds, insects, fungal infestations and other pests. It also includes chemicals used to control stem length in cereals and other plants, and to inhibit the sprouting or growth of suckers. The following are among the important pesticide groups referred to in this report.</td>
</tr>
<tr>
<td><strong>Organochlorine pesticides</strong> are effective against a wide range of insect pests in agriculture, horticulture and forestry. They also have non-agricultural uses, preventing insect and fungal damage in textiles, wood and plaster. They include lindane (gamma-HCH), pentachlorophenol (PCP), dieldrin and DDT. They tend to be highly persistent, toxic to a wide range of animals and to bioaccumulate in the food chain. They were originally considered to have low mobility in the environment as they are relatively insoluble and non-volatile and are strongly absorbed by sediments and soils. Organochlorine insecticides have, however, been found in rivers, into which they have probably been washed on soil particles, and in Antarctica, where they were probably transported in the atmosphere. Many organochlorine pesticides have been banned, or their use restricted, because of their environmental impact.</td>
</tr>
<tr>
<td><strong>Organophosphorus insecticides</strong> protect a wide range of crops against insect pests. They are also used in sheep dip, in aquaticulture, and to treat livestock housing. They tend to be highly toxic to fish, birds, insects and to man. Concentrated solutions of the active ingredient have to be handled very carefully. In general they degrade rapidly in the environment, particularly in soil.</td>
</tr>
<tr>
<td><strong>Triazine herbicides</strong> are used for weed control in agriculture, horticulture, forestry and a wide variety of non-agricultural uses. They include atrazine and simazine. They are relatively non-toxic to mammals but toxic to fish. They are considered persistent and are easily washed off soil slopes if rain follows application. Weeds can develop resistance to them.</td>
</tr>
<tr>
<td><strong>Synthetic pyrethroid insecticides</strong> have replaced many of the organochlorines. They are used to control insects in horticulture, grain storage and agriculture. They are insoluble, non-volatile and persistent in the environment. Most of the group are relatively non-toxic to man or mammals but they are generally very toxic to fish and other aquatic organisms.</td>
</tr>
<tr>
<td><strong>Phenoxy herbicides</strong> are used to control weeds in agriculture, horticulture and grassland, including grass verges. They include mecoprop, 2,4-D and MCPA. They are relatively non-toxic to mammals and man and moderately toxic to fish.</td>
</tr>
</tbody>
</table>

Pesticide transmission to the aquatic environment

7.137 Pesticides enter the aquatic environment from many sources, some of which are discussed in box 7.15 (River Crossens Catchment). Pesticides can be washed off land in pulses at high concentrations after storms (see box 7.16). Such rapid movement may not be surprising in
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catchments where soils overlie impermeable geology at shallow depths and where the fields are
drained and close to the watercourse. The mechanism is far from simple, however, with data
suggesting that pesticides are transported through channels in the soil. Such findings need to be
taken into account in the approval procedure for pesticides which we also discuss in paragraph
7.152.

7.138 Under the Food and Environment Protection Act, applicants for pesticide approval must
provide data from both laboratory and field studies on biodegradation rates and pathways,
adsorption on to soil and mobility and distribution in soil. The movement of pesticides in
predominantly fissured soils into surface waters is poorly understood and it is, therefore,
impossible to quantify inputs under these circumstances. The movement through soils to
groundwaters can be modelled more accurately and predictions can be made using inputs from
the data required for registration. A pesticide that is biodegradable may nevertheless penetrate
through a shallow soil to an aquifer in which there is reduced or almost no biological activity.
Previously it would have been argued that a pesticide that was both biodegradable and strongly
adsorbed could not reach groundwater but it is now recognised that this may not be the case. The
presence of fissures in the aquifer and, more importantly, the climatic conditions prevailing after
the application and during the preceding season will all influence the transfer of pesticides to
groundwater.

7.139 The aquifers which are particularly at risk are those in which rocks are heavily fissured
and underlie shallow soils with a low organic matter content (since organic matter tends to bind
pesticide in soil). Herbicides such as atrazine, simazine, mecoprop and 2,4-D have been found (at
concentrations of 0.2–2.0 micrograms per litre (μg/l)) in chalk aquifers of East Anglia78. Box 7.17
shows other pesticides which have been detected in groundwater. Low microbiological activity
in aquifers, coupled with the natural resistance to degradation displayed by many pesticides, means
that once groundwater is contaminated by these substances it is very difficult to eliminate them.
We discuss in chapter 5 the need for aquifer protection policies to protect groundwater from
contamination by pesticides and other substances.

7.140 The spray drift of pesticides can be hazardous to humans and to the environment and the
Advisory Committee on Pesticides has stated that more needs to be done to reduce offsite drift.
There is evidence that some pesticides can be transported in the atmosphere over considerable
distances. For example, a pesticide used only in China and Korea was found in a Japanese lake
some 1500 kms away. Some long-range transport may arise as a consequence of spray drift but
vapourisation of some pesticides after application may also be a contributory factor. Triazine
compounds have been found in rainwater and DOE has commissioned work to identify both the
degree and sources of pollution from rainwater. We welcome this work and we recommend that
further research be carried out in the UK to assess to what extent the long-range airborne
transport of other pesticides presents an environmental hazard. In addition, the precautionary
approach suggests that more care should be taken to minimise the extent of offsite pesticide drift,
especially when using application techniques which enhance the formation of spray.

Monitoring and the aquatic effects of pesticides

7.141 Much of the information on the levels of pesticides in the aquatic environment is derived
from analysis of water in public supply or from monitoring of water sources to assess their
suitability for abstraction, (see box 7.17). Recent surveys by the Drinking Water Inspectorate79,
Friends of the Earth80 and the Institution of Environmental Health Officers (IEHO)81 have
revealed many cases where the pesticide limits prescribed in the relevant EC directive (0.1 μg/l
for individual pesticides, 0.5 μg/l for total pesticides) have been exceeded. The IEHO survey in
London found that nearly two-thirds of 174 samples of drinking water in a six month survey
carried out in 1989/90 exceeded the EC limits, mainly because of the presence of the triazine
herbicides atrazine and simazine. These findings are in line with those reported by the Drinking
Water Inspectorate for roughly the same area. Over England and Wales as a whole, there were
marked local variations in the incidence of these herbicides in water sources and supplies. The
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BOX 7.15 PESTICIDES IN A RIVER CATCHMENT

Catchments are subject to risks arising from the storage and use of pesticides on farms; these aspects usually form part of the regular farm campaigns which NRA regions carry out to identify and, where possible, eliminate sources of pollution. In April 1990, the North West region carried out a biological survey of the river Crossens in south-west Lancashire where land use is primarily arable, with cereals, root vegetables and salad crops being grown.

The survey indicated that the majority of river sites were of poor or bad quality; out of 24 sites sampled, three were of fair quality (NWC class 2, a reasonable quality for a lowland river system such as this), 14 poor and 7 bad (class 4). The likely causes of this low quality include organic inputs from farms, overflows from the local sewerage system, and pollution from a wildfowl sanctuary. The absence of several pesticide-sensitive species from sites where their presence was expected led the NRA to conclude, however, that pesticide pollution had occurred at eight sites and possibly at a further two.

In the farm pollution campaign, which took place in May 1990, 75 farms were visited; 71 of these were arable and used some pesticides. The NRA found that 34 farms needed construction or repair of pesticide stores and 17 required proper disposal of pesticide washings. River levels in the catchment area are maintained by pumping. This is restricted in dry weather in order to keep water available for growers and, in view of the widespread use of pesticides, the NRA considers it possible that numerous water abstractions for irrigation of treated crops recycle a limited amount of water and concentrate the effect of any chemical run-off.

BOX 7.16 PESTICIDE RUN-OFF

A joint project at the Rosemaund experimental husbandry farm in Herefordshire, involving the Institute of Hydrology, NRA (Welsh Region), MAFF, DOE, BRE and the Soil Survey and Land Research Centre has investigated the mobility and environmental fate of pesticides used under normal agricultural conditions. The experiments clearly show that the movement of some pesticides from agricultural fields to receiving waters can take only a few hours following rainfall and that peak concentrations can be significant. In the spring of 1989, the project showed that about 0.3% of simazine applied 8 days earlier to adjacent land was accounted for in the near-by stream, where a mean concentration of 30 micrograms per litre (µg/l) was recorded during a period of 16 hours in which 13.5mm of rain fell. A peak concentration of 68 µg/l was reached (for less than an hour) six hours after the start of the rain event, but levels had dropped to below 3 µg/l after 29 hours. Further rainfall over a week later resulted in 0.05% of the applied simazine reaching the stream, giving a mean concentration of 8 µg/l and peak concentration of 15 µg/l. The mass of each pesticide accounted for in the stream was only a small proportion of the total amount applied to the field. The magnitude of the concentrations appears to depend on the amount and half-life of the pesticide applied (apart from its solubility), and the amount and timing of any following rainfall.

Source: Pesticide run-off study at Rosemaund EHF, Report of years one to three, nd.

Drinking Water Inspectorate reported that 33 individual pesticides were detected at concentrations above 0.1 µg/l in 1989 and 34 in 1990, a total of 43 individual pesticides in the two years. This amounted to slightly over 2% of the analyses carried out. Atrazine, simazine, isoproturon, chlorotoluuron and mecoprop were detected most frequently in both years. The Inspectorate stated that the concentrations of pesticides detected were far smaller than amounts which are known to be harmful or are likely to damage public health.22
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BOX 7.17 PESTICIDES IN GROUNDWATER AND SURFACE WATER

Most information about the presence of pesticides in freshwater is obtained from analyses of water abstracted for public supply. Friends of the Earth has reviewed data from water suppliers for the years 1985-87 to identify drinking water sources containing concentrations of pesticides above the maximum admissible concentration (MAC) specified in the EC drinking water directive (0.1 µg/l for a single pesticide and 0.5 µg/l for total pesticides). The table shows the ranges of pesticide concentrations found in the samples which exceeded the MAC and the number of sources affected. (Reservoir, blended and unknown sources are excluded.) More breaches and higher concentrations were recorded for surface water than for groundwater. The breaches occurred mainly in the Anglian, Severn-Trent, Thames and Wessex regions. One Water Authority did not respond to the survey.

<table>
<thead>
<tr>
<th>PESTICIDE</th>
<th>NO OF SOURCES WHERE MAC WAS EXCEEDED - GROUNDWATER</th>
<th>RANGE OF CONCENTRATIONS (µg/l) - GROUNDWATER</th>
<th>NO OF SOURCES WHERE MAC WAS EXCEEDED - SURFACE WATER</th>
<th>RANGE OF CONCENTRATIONS (µg/l) - SURFACE WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine</td>
<td>32</td>
<td>0.11-0.48</td>
<td>32</td>
<td>0.11-1.85</td>
</tr>
<tr>
<td>Simazine</td>
<td>14</td>
<td>0.11-0.42</td>
<td>26</td>
<td>0.11-1.97</td>
</tr>
<tr>
<td>Mecoprop</td>
<td>1</td>
<td>0.36</td>
<td>13</td>
<td>0.12-0.98</td>
</tr>
<tr>
<td>MCPA</td>
<td>1</td>
<td>0.42</td>
<td>7</td>
<td>0.16-0.84</td>
</tr>
<tr>
<td>MCPB</td>
<td>7</td>
<td>0.16-0.41</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2,4-D/MCPA</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>0.17-0.96</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>0.12-0.24</td>
</tr>
<tr>
<td>2,4-D</td>
<td>3</td>
<td>0.24-0.56</td>
<td>2</td>
<td>0.11-0.56</td>
</tr>
<tr>
<td>2,4,5-T</td>
<td>5</td>
<td>0.26-0.50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dichlorprop</td>
<td>1</td>
<td>0.20</td>
<td>2</td>
<td>0.12-0.28</td>
</tr>
<tr>
<td>Bromoxynil</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>0.18-1.40</td>
</tr>
<tr>
<td>Linuron</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>0.20-0.76</td>
</tr>
<tr>
<td>Chlorotoluron</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.44-0.58</td>
</tr>
<tr>
<td>Propazine</td>
<td>4</td>
<td>0.11-0.27</td>
<td>2</td>
<td>0.25-0.47</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.18</td>
</tr>
</tbody>
</table>

7.142 The statutory maximum admissible concentrations set for pesticides in drinking water have been widely criticised as having no toxicological basis. The limit of 0.1 µg/l which applies to any individual pesticide is believed to be based on a one-time limit of detection for chlorinated insecticides. As such it was regarded as a surrogate zero and was combined with a limit for total pesticides of 0.5 µg/l. Earlier limits set by the US Environmental Protection Agency (in 1976) and Welfare Canada (in 1978) were based on the toxicity of individual pesticides and this approach was adopted by the World Health Organisation (WHO) in its Guidelines for Drinking Water Quality published in 1984 to provide guidance to bodies responsible for setting national standards. Most of the guideline values set by WHO for pesticides exceeded 0.1 µg/l but some were less than this. The Department of the Environment in 1989 published its own advisory values for a wide range of pesticides likely to be found in water. These were based on an approach similar to that adopted by WHO. The Government is pressing the EC Commission to review the limits for pesticides. Although the consideration of limits for drinking water is outside the scope of this report, we consider that there should be a mechanism for the revision of limits in the light of new knowledge and in chapter 9 we recommend that the Government should encourage the EC Commission to develop proposals to this end.

7.143 The WHO pointed out that its recommended guideline values are set at a level to protect human health; they may not be suitable for the protection of aquatic life. Experience has shown
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this to be the case. It is difficult to predict the effects on aquatic organisms of the many existing pesticides and their combinations and there is no effective way of assessing the environmental effects of long term exposure. In view of these considerations and of the findings reported above, we consider that fundamental work is needed to explore the mechanisms by which pesticides affect aquatic organisms. In addition, the long term environmental effects of prevailing concentrations and the potential synergistic effects of mixtures of pesticides and their degradation products which are now being found in freshwaters should be carefully monitored. We also consider that more active measures are needed to prevent pesticides from reaching both surface and groundwater.

7.144 Tecnazene is used as a fungicide and sprouting inhibitor on potatoes. In 1988, 35% of the crop in England and Wales was treated with the product. Tecnazene has a narcotic effect on fish and a tentative safe limit for fish of 1 µg/l has been adopted by MAFF and the NRA. Tecnazene and its two major breakdown products, tetrachloraniline and tetrachlorothioanisole, are commonly found in the effluents of potato washing plants and, to a lesser extent, those from fish and chip shops and domestic sources. Tetrachloraniline is more acutely toxic to a range of aquatic life than tecnazene itself. Effluents from domestic and catering sources and from those washing plants which are semi-mobile are difficult to control, and in general the extent of pollution is hard to assess because of the variability of tecnazene concentrations in effluents. A study by MAFF of an Essex river revealed concentrations in the river downstream of the effluent from a potato washing plant, and in the effluent itself, ranging from 0.5 µg/l to 720 µg/l. The survey was not of a nature to indicate whether this is a normal range, but concentrations of up to 3,000 µg/l have been recorded in the effluent of a food processing factory in Cornwall. A survey carried out for DOE showed that the majority of sites downstream of potato washing plants were contaminated with tecnazene and its breakdown products, with a concentration of 1 µg/l being exceeded in over 40% of samples. The Advisory Committee on Pesticides (ACP), which is currently reviewing tecnazene, has stated that discharges from potato washing plants posed a serious problem as there was a high risk of the compound entering the aquatic environment and being retained in effluent. Some supermarkets specify that potatoes supplied to them should be free from tecnazene. We welcome the steps being taken to identify the risks to the aquatic environment as well as to consumers of potato products and we look forward to the conclusion of the ACP's review of the approval at present given to tecnazene.

7.145 A survey carried out in the UK during 1986–1987 found eels containing residues of dieldrin above the guidance level of 0.1 mg/kg specified by the Department of Health, above which there is a potential health risk to regular consumers. The highest level found was 4.1 mg/kg in a sample from the Leeds–Liverpool canal; the mean residue in eels from this source was five times the guidance level. News Releases in October 1988 and May 1991 advised people to consider restricting their consumption of locally caught eels. The Working Party on Pesticide Residues considered that the eels also posed a potential threat to fish-eating birds and mammals. Approvals for the agricultural uses of dieldrin were withdrawn during the 1970s, and for all other uses in March 1989.

7.146 There is scope for improving the monitoring of water bodies for the presence of pesticides. Apart from the analysis of water for public supply, and monitoring by the NRA and RPA, for certain pesticides which are list I substances, there is no defined programme of monitoring, no established list of pesticides to be monitored, no statistically valid pattern of monitoring and no list of sites chosen for the likelihood of their contamination by pesticides. The range of pesticides which might merit monitoring is very large, particularly if analysis were extended to those decomposition products which are of concern. Chemical analysis can be complex and expensive, since the compounds may be present only in very small concentrations. Nevertheless, we consider that monitoring for pesticides requires a more positive approach. Pesticides have toxic properties and their presence in the aquatic environment, even at very low levels, is a matter of legitimate concern because of potential impacts on wildlife which may be very long term, and because of the importance of safeguarding drinking water supplies, for which very low pesticide limits have been set. We therefore recommend that the regulatory authorities and the water undertakers should extend and improve their monitoring programmes for
pesticides in surface and ground waters and should periodically analyse and publish the results. A knowledge of pesticide usage in the catchment would form a sound basis for the monitoring programme and there is scope for co-operation here between the suppliers and users of pesticides on the one hand and the bodies sampling for them on the other. We discuss below ways in which data, particularly on the use of non-agricultural pesticides, could be improved.

**Box 7.18 Agricultural Pesticide Usage**

Trends in pesticide usage are affected by changes in the crops grown and in husbandry techniques as well as by developments in the kind of pesticides used. The quantity of organochlorines used decreased in the early 1980s but the area treated increased, mainly because of the use of gamma-HCH on the expanding area of oilseed rape. With many of the organochlorine pesticides now banned in the UK because of their toxicity and persistency, the amounts used will continue to decline. This may be offset by increased use of replacements such as the organophosphorus and synthetic pyrethroid insecticides. The quantity of organophosphorus compounds used increased by one quarter during the 1970s but has remained relatively stable since then.

The application of fungicides to cereals came into prominence in the early 1970s and there has been a large increase in use during the 1980s.

Although the area of cereals planted with seeds treated with pesticides has varied only a little, the use of more efficient products, applied at lower rates of active ingredient, has led to a reduction in the quantity of active chemicals.

During the late 1970s and early 1980s there was a marked increase in the use of herbicide. Most of this increase related to cereals and other arable crops but there was also a larger area of grassland treated.

Other pesticides such as growth regulators, soil sterilants and fumigants have shown a variable but upward trend in usage. Most of the recent increase is due to the use of chlorimequat as a growth regulator in wheat.

**Current usage**

7.147 Data on pesticide usage in different agricultural and horticultural sectors are produced by MAFF. Table 7.8 gives data for usage on cereals. Trends in agricultural pesticide use are outlined in Box 7.18. Since 1980, the area treated has continued to increase slowly but the introduction of new active ingredients, which are effective at lower rates of application, has led to a steady decline in the total quantity of active ingredient applied. In 1990, some 14,323 tonnes of pesticide by active ingredient were applied to cereals, of which 54% were herbicides, 25% fungicides, 16% growth regulators and 2% insecticides.

7.148 Data on other uses of pesticides are relatively limited. In 1974, the DOE published a report on the non-agricultural uses of pesticides in Great Britain and in 1991 a review of non-agricultural herbicide use was published. About 180 products were approved under the Control of Pesticides Regulations 1986 for use on grass or for the control of vegetation in non-crop areas. The review showed that in 1989 some 550 tonnes of herbicide (by active ingredient) were used for non-agricultural purposes mostly using products formulated specifically for the non-agricultural sector. Table 7.9 compares these tonnages with estimates of the agricultural use of the same herbicides. British Rail, one of the major users of atrazine, recently decided to discontinue its use and to experiment with environmentally less persistent substitutes. We welcome the review of the approvals of atrazine, simazine and isoproturon which is being carried out by the Government’s Advisory Committee on Pesticides. We recommend local authorities, which are major users of pesticides, to seek to reduce their application and to use less environmentally harmful formulations.
Plate 23  Iron oxide and sulphur pollution in the river Pelena, near Port Talbot, from an abandoned coal mine.

*Photograph by courtesy of Roger Hutchings/Network Photographers.*

Plate 24  Discolouration of the river Carnon, Cornwall, caused by heavy metals from the Wheal Jane tin mine.

*Photograph by courtesy of NRA South West Region.*
Plate 25  Pollution of the upper reaches of the river Tame in Walsall, West Midlands. About six tonnes of copper and 15 tonnes of nickel are estimated to seep into this river each year from this and a nearby site.

*Photograph by courtesy of NRA Severn-Trent Region.*

Plate 26  Pollution of a tributary of the river Clyde. 20,000 litres of phenolic tar entered the stream following a road accident involving a tanker carrying the tar from Ravenscraig Steelworks.

*Photograph by courtesy of Clyde River Purification Board.*
Plate 27  Field drainage pipe with silage effluent.
*Photograph by courtesy of Graham Burns/Environmental Picture Library.*

Plate 28  Salmon fish farm at West Loch Tarbert, Outer Hebrides.
*Photograph by courtesy of Michael Martin/Science Photo Library.*

Plate 29  Small fish farm at Thurlaston, Warwickshire.
*Photograph by courtesy of Martin Bond/Science Photo Library.*
Plate 30  National water sports centre at Holme Pierrepont, Nottingham.
Photograph by courtesy of National Water Sports Centre, Nottingham.

Plate 31  Artificial canoe slalom course at Holme Pierrepont, Nottingham.
Photograph by courtesy of T.C. Middleton/Oxford Scientific Films.
Table 7.8
Pesticide usage on cereals 1974 to 1990: England and Wales

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</thead>
<tbody>
<tr>
<td>Herbicides</td>
<td>4,472</td>
<td>8,725</td>
<td>4,577</td>
<td>7,582</td>
<td>7,395</td>
</tr>
<tr>
<td>Fungicides</td>
<td>571</td>
<td>394</td>
<td>977</td>
<td>569</td>
<td>5,247</td>
</tr>
<tr>
<td>Insecticides</td>
<td>46</td>
<td>17</td>
<td>534</td>
<td>194</td>
<td>535</td>
</tr>
<tr>
<td>Seed Treatments</td>
<td>3,320</td>
<td>536</td>
<td>3,273</td>
<td>497</td>
<td>3,189</td>
</tr>
<tr>
<td>Growth Regulators</td>
<td>42</td>
<td>71</td>
<td>188</td>
<td>239</td>
<td>770</td>
</tr>
<tr>
<td>Molluscicides</td>
<td>25</td>
<td>13</td>
<td>33</td>
<td>9</td>
<td>550</td>
</tr>
<tr>
<td>Total on cereals</td>
<td>9,757</td>
<td>9,090</td>
<td>16,708</td>
<td>15,690</td>
<td>14,313</td>
</tr>
</tbody>
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</tr>
</thead>
<tbody>
<tr>
<td>Area of Cereals grown '000 hectares</td>
<td>3,246</td>
<td>3,209</td>
<td>3,444</td>
<td>3,318</td>
</tr>
<tr>
<td>Total Pesticide treated area '000 hectares</td>
<td>8,476</td>
<td>9,582</td>
<td>17,686</td>
<td>20,407</td>
</tr>
</tbody>
</table>

NB: The sum of individual columns may differ from the totals shown because of rounding.
Treated area = the gross area treated with a pesticide, including all repeated applications.
Source: MAFF Pesticide Usage Surveys – Arable Farm Crops and Grass
Chapter 7

Table 7.9
Non-agricultural usage of herbicides in England and Wales, 1989

<table>
<thead>
<tr>
<th>Non-agricultural use</th>
<th>Agricultural and Horticultural use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnage</td>
<td>Tonnage</td>
</tr>
<tr>
<td>Atrazine</td>
<td>138</td>
</tr>
<tr>
<td>Simazine</td>
<td>77</td>
</tr>
<tr>
<td>Diuron</td>
<td>66</td>
</tr>
<tr>
<td>2, 4-D</td>
<td>50</td>
</tr>
<tr>
<td>Mecoprop</td>
<td>44</td>
</tr>
<tr>
<td>Amitrole</td>
<td>39</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>28</td>
</tr>
<tr>
<td>Sodium Chlorate</td>
<td>22</td>
</tr>
<tr>
<td>MCPA</td>
<td>22</td>
</tr>
</tbody>
</table>

Tonnages refer to active ingredients


7.149 No figures are available on the size of the domestic market for pesticides in the UK but it is likely to be small compared to the agricultural and industrial markets. Products approved for home or garden use generally contain low concentrations of active ingredient and the evaluation of the products before approval is granted takes account of the special circumstances of domestic use. It is possible that some households dispose of waste pesticides into sewers but their dilution should be sufficient to preclude any acute adverse effects on the biological treatment processes of sewage works or on aquatic organisms. We urge, however, that more care should be taken both to improve the legibility of labels and instructions, and consistently to provide clear guidance on the safe disposal of surplus products.

7.150 Some of the non-agricultural uses of pesticides are for safety or to protect health. Others are for aesthetic reasons — to preserve weed-free lawns and golf-courses or inhibit plant growth in such places as road-side verges. The persistence and harmfulness of many pesticides makes it appropriate, however, to adopt a precautionary approach to their use. In particular, there may be a value in developing the concept of best practice in the use of pesticides. This would emphasise the need to use pesticides which cause the least consequential damage to other parts of the environment. The limitations of the data on non-agricultural pesticide use make it difficult, however, to develop a complete picture or formulate a comprehensive policy. We therefore recommend that periodic surveys of the non-agricultural uses of pesticides should be commissioned by the Government and the results published. These results should indicate the tonnage of active ingredients used, the categories of user and the broad locations of use.

Assessment of pesticides and their review

7.151 Pesticides vary in their chemical and physical characteristics and, as we point out in paragraph 7.138 the mechanisms governing their mobility and potential to degrade in the aquatic environment are imperfectly understood. Much of the information available on the toxicity of pesticides to aquatic organisms relates to a limited range of test organisms such as rainbow trout, *Daphnia* and *Chlorella*, and to acute rather than chronic toxicity. Similarly, although information is available on the chemical and bio-degradation of pesticides, it does not uniformly cover their persistence under natural conditions.
7.152 With increasing knowledge of ecotoxicology and the mechanisms by which pesticides enter the environment, degrade, or accumulate, it will be necessary to continue to update the test procedures which produce the data for the assessment of pesticides under the Food and Environment Protection Act. Under that Act, existing pesticide approvals will be reviewed on a 10 year cycle and this could provide the opportunity to upgrade the data to meet modern requirements. We recommend that research on ecotoxicology and the mechanisms governing the distribution and fate of pesticides in the environment should continue. Particular emphasis is needed on the factors affecting both surface and groundwater contamination and on the development of test procedures for assessing the propensity of individual pesticides to contaminate water and affect organisms in it. When new products are being assessed for approval, the process should be as rapid as is consistent with a proper evaluation of all relevant health, environmental and other risks. This could enable safer, more specific products to replace less desirable ones. We are glad to note the increased resources which MAFF has applied to pesticide assessment since 1990. We note the plea of the Advisory Committee on Pesticides for an improvement in the quality of presentation of the data put to the Committee so that evaluations can be prepared as quickly as possible.

Disposal of waste from pesticide manufacture

7.153 Effluents from the manufacture and formulation of pesticides are subject to consent, either by the NRA if discharged directly, or by the sewerage undertaker if discharged to sewer. Both consenting authorities would normally require pre-treatment. The concentration of pesticides in effluent can be reduced before discharge by such procedures as flocculation, coagulation and treatment with activated carbon, often in combination. It is important that the designers of treatment processes consider the ultimate fate of pesticides and ensure that the pollution problem is not simply moved elsewhere or even exacerbated. It is equally important that the treatment processes are carried out conscientiously since a failure in them could incapacitate the biological processes at a sewage treatment works or kill organisms in rivers. We recommend that manufacturers progressively improve their recovery and treatment processes until no effluent leaves their works without having been rendered effectively inert.

Disposal of waste pesticides by farmers and other users

7.154 Many pesticides are List I substances under the EC groundwater directive\textsuperscript{48} under which Member States are to prohibit all direct and indirect discharges which could contaminate groundwater. Implementation of the directive means that List I substances cannot be disposed of via soakaways or many landfill sites. MAFF's Code of Good Agricultural Practice for the Protection of Water, revised in July 1991, suggests a number of ways of disposing of waste pesticides and spray-tank washings. These continue to include, albeit subject to important qualifications such as the approval of the NRA or local WSC, disposal onto waste ground of little wildlife value or into a soakaway that is designed and built properly. We consider that this guidance does not stress sufficiently the importance of ensuring that pesticides are disposed of in ways which do not cause pollution of water or other media. It also provides confusing advice to the user, for example by recommending that soakaways are a permissible disposal route whilst also warning that they are not suitable in most places because of the risk of polluting ground water. Nor does the guidance point out that, whereas certain pesticides disposed of on the surface will biodegrade, they will do so either much more slowly or not at all if disposed of via soakaways. We recommend that MAFF's guidance on the disposal of pesticides by farmers be further revised.

7.155 Growing concern about the disposal of pesticides has led to interest in avoiding the creation of pesticide wastes entirely or, when some waste is unavoidable, developing better application techniques and safer methods of disposal. Modern instrumentation allows the skilled operator to mix no more than the quantity of spray required for any given job. Integral tank washing devices allow the washings to be quantified and used as a final application. Wider use of such systems (and several are now on the market) would reduce farmers' needs to dispose of spray tank residues. ICI has devised a plant for use on farms to treat pesticide waste using the industrial techniques mentioned in paragraph 7.153. At present the plant will cope with most pesticide
wastes except sheep dip (which, though it contains pesticides, is classed as a veterinary medicine and hence subject to a different licensing procedure) but the resulting pesticide-rich sludge could still pose a threat to freshwater if it were disposed of in unsuitable sites. The cost of such equipment means that it might be most beneficial when operated by waste disposal contractors visiting farms with a treatment service or to whom farmers could bring their residues. We recommend that the Government seek ways of encouraging the use of such systems. In addition, a scheme to collect unwanted or unapproved pesticides from farms was announced in August 1991. The scheme, of four months’ duration, allowed such pesticides to be transferred to suitable commercial stores prior to their safe disposal. We welcome this arrangement and we recommend that the merits of establishing a similar scheme for non-agricultural pesticides and animal health products containing pesticides should be evaluated.

General practices
7.156 Veterinary drugs (including sheep dips) are licensed by the grant of a product licence under the Medicines Act 1968. Pesticide use, on the other hand, is controlled by the Food and Environment Protection Act 1985 (FEPA) and regulations made under it, and by the Control of Substances Hazardous to Health Regulations 1988 (COSHH), made under the Health and Safety at Work etc Act 1974. Under FEPA everyone involved in the use of pesticides must have adequate training in their safe and efficient use. Those who apply (or supervise the application of) agricultural pesticides and were born after 1964 are also required to hold certificates of competence. COSHH requires employers to safeguard themselves and any other persons affected by the work carried out by the employer. This legislation is still fairly new and in time it, together with recent guidance, may be expected to lead progressively to changes of practice on farms. People involved in the non-agricultural use of pesticides, such as employees of British Rail, local authorities and industry, are also required to have adequate training in their safe and efficient use. We recommend that those non-agricultural employees who apply pesticides (or supervise their application) should, in addition, be required to hold a certificate of competence. A certificate of competence is not required when the substances being used come within the terms of a Medicines Act Trials Certificate or product licence. The Health and Safety executive are aware of this gap and we look to its being filled quickly.

7.157 A reduction in the use of pesticides would help to decrease the levels found in water. In some instances, this might be achieved by new management practices and controls. The MAFF Code of Practice on Pesticides goes some way to recommend reduced use by suggesting that ‘pesticides should only be used when necessary, in relation to efficient production, if the consequences of not using them significantly outweigh the risks to human health and the environment of using them’. This should be a challenging test. But it places the burden of the decision on the pesticide user who, though familiar with local conditions and experienced in crop management, weed or infestation control, is unlikely to be able to make such an assessment unaided. MAFF told us that the Ministry already operates a £20 million research and development programme particularly aimed at reducing pesticide usage. Projects include the investigation of when pesticides should be used, and the development of alternative control methods such as integrated pest management systems, biological controls and more disease resistant crop varieties. ADAS promotes integrated pest management and advises on minimum pesticide use. Non-agricultural users, on the other hand, appear to have few obvious sources of advice on ways of reducing pesticide application and there is scope for the Government to take a more active role in developing policies to minimise use and disseminating information to other categories of user.

7.158 We suggest elsewhere that the Government should produce a water policy plan for the UK with specific targets for attainment. Timetables for the reduction of pesticide usage have been set in Germany, the Netherlands and Scandinavia. We recommend that a similar national strategy (including a timetable) for reducing pesticide use should also form part of the UK’s water policy plan. We are doubtful, however, of the value of a global percentage reduction target. It is too easy to manipulate figures by concentrating on heavily used substances which cause few problems, whilst ignoring highly toxic pesticides used at much lower tonnages. Targets should be
related to individual pesticides, taking particular account of their toxicity and persistence in the environment as well as of the results of the research referred to in paragraph 7.157. The targets will also have to take into account the UK’s commitment to reduce inputs to the North Sea of Red List substances. We recommend that the national strategy should encourage further research and development of pesticides which are specific in their effect, degrade rapidly in the environment, and do not harm parts of the environment which they are not intended to control.

PATHOGENIC MICRO-ORGANISMS IN FRESHWATER

Waterborne diseases

7.159 Domestic sewage contains huge numbers of micro-organisms of faecal origin. Secondary treatment can remove a high proportion of bacteria and viruses from the sewage (see table 7.2) but sufficient quantities may still be present to contaminate rivers and lakes used for recreation. Average counts in settled crude sewage of the thermotolerant coliform bacteria used as an indicator of faecal contamination may be 20 million per 100 ml (see table 7.10). Even after effective biological treatment, counts in the effluent may be 200,000 per 100 ml91. Birds and other wildlife, livestock slurries, and effluents from animal processing industries may also introduce microbiological pathogens into water. The risk of polluting drinking water supplies with these effluents has long been recognised, so that public health measures to prevent outbreaks of disease from this route are a major consideration for the water and sewerage industry and the public health authorities. Groundwaters generally contain far fewer micro-organisms. The overlying soil normally filters many of them out before they reach aquifers, and there is little nutrient present to support their growth. Shallow wells and boreholes can, however, become contaminated.

Table 7.10
Some thermotolerant coliform counts

<table>
<thead>
<tr>
<th>Site</th>
<th>Counts per 100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland stream upstream of</td>
<td>750</td>
</tr>
<tr>
<td>any human habitation</td>
<td></td>
</tr>
<tr>
<td>One Dorset river downstream</td>
<td>1,000</td>
</tr>
<tr>
<td>of the first hamlet</td>
<td></td>
</tr>
<tr>
<td>Three Dorset rivers</td>
<td>1,000 to 4,200</td>
</tr>
<tr>
<td>Two rivers by coastal sites</td>
<td>220 to 170,000</td>
</tr>
<tr>
<td>Settled crude sewage (24 hour average)</td>
<td>20,000,000</td>
</tr>
</tbody>
</table>

7.160 Cryptosporidiosis has nevertheless been contracted in the UK from drinking water because the treatment processes for the supplies involved were not completely able to remove or destroy the pathogen. Giardiasis is believed to have resulted from drinking infected water92 (see box 7.19). Leptospirosis may be contracted through the recreational use of water; and legionellosis from the use of poorly maintained, water-cooled air-conditioning systems (see box 7.20).

7.161 Following outbreaks of cryptosporidiosis in Swindon and parts of Oxfordshire in 1989 an expert group was established to advise the Government on the significance of cryptosporidium in water supplies93. The report stated that, although cryptosporidiosis can be waterborne, this route of exposure probably accounts for only a small proportion of cases. Oocysts (the infectious stage of cryptosporidium) are resistant to chlorination, and conventional treatment methods for water supply cannot be guaranteed to remove them. Source protection is therefore important. The report recommended that, in order to minimise the risk of contamination from animal manures, MAFF should review the advice given to farmers on their storage and disposal (particularly close to water abstraction points) and, in the longer term, should promote the development of safer
methods for their use. The report also set out a comprehensive research programme covering improved methods of isolating and enumerating Cryptosporidium, assessing its viability, infectivity and occurrence, and its removal in water treatment, and establishing the epidemiology of cryptosporidiosis. This work is being funded mostly by DOE with support from several other bodies.

7.162 Giardiasis is another diarrhoeal disease caused by a protozoan parasite which can be waterborne, although in this case (unlike cryptosporidiosis) there is no evidence of an association with agricultural pollution. Well’s disease or icteric leptospirosis (see box 7.20) can also be transmitted from animals to man via water. Contamination of the water by urine from infected rats is usually implicated, although this and other types of leptospirosis are widespread in many domestic and wild animals.

**BOX 7.19 CRYPTOSPORIDIOSIS AND GIARDIASIS**

**Cryptosporidiosis**
Cryptosporidiosis is caused by the protozoan parasite Cryptosporidium parvum which is found in man and other mammals. The prevalence of cryptosporidium in livestock makes it likely that most oocysts in the environment derive from agricultural sources. Outbreaks of infection in animals usually involve calves or lambs and these animals are likely to form the most important reservoirs of infection for man. In humans, infants are rather more susceptible to infection than adults. In normally healthy patients the disease results in a self-limiting gastro-enteritis with diarrhoea and flu-like symptoms; in the immunologically compromised, the outcome is far more serious with life-threatening diarrhoea. The normal route of exposure is faecal–oral, infection occurring directly from animal to man, from person to person or through contaminated water or food. In the case of infection, the critical form of the parasite is the oocyst, 4–6 microns in diameter, shed in vast numbers in the faeces of infected animals and people. An oocyst can survive outside a host for a considerable period and, once it has infected a new host, can multiply and produce disease rapidly.

**Giardiasis**
Giardiasis is a diarrhoeal disease caused by a protozoan parasite which can be waterborne. The presence in UK waters of Giardia intestinalis, the causative organism, is unusual because of the lack of a native population of wild animals that provide a natural reservoir of infection. Contamination can arise from the infection of individuals during overseas travel and the presence of the parasite in sewage effluent. In contrast to Cryptosporidium, Giardia is less likely to survive normal treatment processes applied to surface waters.

7.163 The public health authorities recognise the importance of rapidly identifying outbreaks of diseases such as these so that appropriate action can be taken. The prevalence of microbial pathogens in natural waters and the mechanisms by which they can infect man through the use of water are not well understood. Further investigation of the presence and sources of the pathogens in freshwaters is an important priority, so that the risks they pose, especially for the recreational use of freshwaters, can be more fully assessed and publicised.

**Use of freshwater for recreation**
7.164 In recent years there has been a substantial growth in sporting pursuits, such as water skiing, sail boarding, dinghy sailing, power boating and canoeing as well as angling, swimming and motor cruising. These take place not only on rivers, canals and lakes but also extensively on reservoirs, most of which are operated by water supply companies or British Waterways (BW). To take a single example, BW manages some 2,000 miles of inland waterways and 90 water supply reservoirs for purposes including recreation and leisure. Bathing is generally prohibited in BW waters but it is estimated that several million visits are made annually for other recreational activities (see table 7.11). The number of powered pleasure craft licensed or registered in the
**BOX 7.20  LEPTOSPIROSIS AND LEGIONELLASIS**

**Leptospirosis**

Leptospirosis is caused by *Leptospira interrogans*, a bacterial spirochaete whose various serotypes (more than 200 in all) are capable of infecting a wide range of wild and domestic animals. Infectious leptospires are excreted in the urine of the afflicted animal. Icteric leptospirosis (Weil's disease) can be transmitted to man via water polluted with the urine of rats infected with the *icterohaemorrhagiae* strain of *Leptospira interrogans*. Infection occurs via the mucous membranes of the conjunctiva, nose and mouth and via open wounds and abrasions of the skin. Man may therefore acquire leptospirosis through accidental, occupational or recreational contact with contaminated water or through direct contact with the urine, fluids or tissues of infected animals. Between 1985 and 1989, there were 299 reported cases of leptospirosis in England and Wales. Twenty were associated with canoeing and twenty nine had other contact with water.

**Legionellosis**

The causative organism of legionellosis are species of the bacterium Legionella, with *Legionella pneumophila* accounting for over 80% of investigated cases of the pneumonia-like Legionnaires' Disease and of the milder Pontiac Fever. The organism is widely distributed but is particularly associated with warm, stagnant waters, their biofilms and microbial sludges. It would appear to be an opportunistic pathogen, capable of infecting only particularly susceptible individuals who inhale small (aerosol) droplets of the contaminated water. Reduction of the microbial burden, for example by regular cleaning and chlorination of water-cooled air-conditioning systems is recommended as a preventive measure.

<table>
<thead>
<tr>
<th>Table 7.11</th>
<th>Recreational activities in waters managed by British Waterways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Activity</td>
<td>Estimated number of separate visits per year (1990)</td>
</tr>
<tr>
<td>Power boating</td>
<td>0.7</td>
</tr>
<tr>
<td>Unpowered boating</td>
<td>1.5</td>
</tr>
<tr>
<td>Angling</td>
<td>17.3</td>
</tr>
<tr>
<td>Informal bankside activities</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Source: British Waterways

1987/88 season included 19,829 on BW waters, 11,521 on the Thames, 6,625 on Anglian Waterways and 5,464 on the Norfolk Broads. In 1988 it was estimated that the national ownership of canoes was approximately 0.5 million and that a further 0.6 million individuals participated in canoeing.

7.165 The governing bodies of some sporting associations and the managers of inland waters, such as British Waterways, showed us evidence of their increasing concern about the potential health risks posed by microbiological contamination of inland waters. British Waterways told us that sample surveys carried out recently at some of their sites in urban areas showed that many would not comply with the standards in the EC directive concerning the quality of bathing water (76/160/EEC) (see box 7.21) The British Long Distance Swimming Association reported that the Great Ouse swimming event was cancelled because of microbiological pollution well in excess of

135
The EC directive was agreed in 1975. It defined bathing water as all running or still freshwaters or parts thereof and sea water, in which bathing is explicitly authorised by the competent authority of each member state, or bathing is not prohibited and is traditionally practised by a large number of bathers. The directive specifies sampling frequencies and percentage compliance requirements for both microbiological and chemical parameters of water quality. No restriction is placed on bathing in waters which are not identified or which do not attain the standards specified in the directive.

For the 1990 bathing season the UK identified 446 bathing waters of which 345 complied with the standards set in the directive. In 1991 76% of the 453 waters identified for that season met the mandatory coliform bacteria standards of the directive. The UK and Ireland are the only member states which have not identified any freshwater bathing areas under the directive.

The directive sets mandatory and/or guide values for 5 microbiological parameters — total coliforms, faecal coliforms, faecal streptococci, salmonella and enteroviruses — and these are shown below. 95% compliance is required for mandatory values, 80% for guide values (90% for faecal streptococci) for samples taken 30 cm below the surface during the bathing season, when monitoring should be fortnightly.

**Microbiological quality requirements of the EC bathing water directive.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Guide value</th>
<th>Mandatory value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliforms/100ml</td>
<td>500</td>
<td>10,000</td>
</tr>
<tr>
<td>Faecal coliforms/100ml</td>
<td>100</td>
<td>2,000</td>
</tr>
<tr>
<td>Faecal streptococci/100ml</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>Salmonella/litre</td>
<td>—</td>
<td>0</td>
</tr>
<tr>
<td>Enteroviruses/10 litre</td>
<td>—</td>
<td>0</td>
</tr>
</tbody>
</table>

The risk that pathogens from sewage sources may be present in water is usually assessed by monitoring for more prevalent and easily detected faecal indicator bacteria, such as *Escherichia coli* (*E. coli*) or total coliform bacteria. This technique has been in use for the past 80 years. The presence of *E. coli* does not necessarily imply the presence of pathogens: pathogenic organisms will be present only when cases of disease exist in the community. Conversely the absence of *E. coli* does not confirm the total absence of pathogens since pathogens may be more robust in the environment than *E. coli*. Secondary indicators, such as streptococci, have been included in measures of the microbiological quality of water for bathing because they are more resistant to decay.

The results of microbiological surveys are heavily influenced by weather conditions and the route of pollution. In general, bacterial counts in freshwaters increase after storms as a result of surface run-off and combined sewer overflows and the resuspension of bacteria from sediments. The microbiological contamination of water by bacteria from animals is particularly high during heavy rain or after snow has melted. Many microbiological tests take some time to carry out. Hence although they provide data on the condition of the water at the time the sample was taken, they cannot estimate the immediate risk to be incurred from immersion in a waterbody. In general, the micro-organisms monitored in fresh lowland water are those arising from human sewage rather than from animal sources. Yet some micro-organisms derived from animal sources can infect and cause disease in man. Several institutes in the UK are currently carrying out research into developing quicker methods for assessing the microbiological quality of water and detecting the presence of pathogens of animal origin, such as leptospires and *Cryptosporidium* in freshwater.
the EC standards and that an event on Windermere was cancelled because of a bloom of blue-green algae. The British Canoe Union reported that some canoeists had suffered from diarrhoea and vomiting at slalom course Holme Pierrepont at Nottingham (see plate 31). The Public Health Laboratory Service told us that surveys have shown that a high proportion of inland sites used for recreational purposes would not comply with the standards of the EC bathing water directive, were they to be applied to such sites. The NRA has stated that rivers do not, in general, meet the coliform criteria of the EC directive but that many inland still waters which do not receive sewage effluent and have low inputs from diffuse sources are of high bacterial quality.

7.166 The possibility that water recreation might involve a risk of contracting infectious disease has prompted numerous studies. The assessment of the health risks associated with bathing and other water immersion activities is not straightforward because of difficulties in obtaining representative exposed and control groups, in the precise diagnosis of illness and in identifying significant differences in bacterial and/or viral counts between polluted and unpolluted waters surveyed. Most studies have relied upon interviews of bathers and non-bathers in a recreational area with follow-up interviews to ascertain the incidence of illness.

7.167 Most studies have been on sea-bathing but some have looked at inland waters. The latter have focused not on notifiable diseases, which are now rare, but on symptoms associated with gastroenteritis, respiratory illness and infections of the ear, nose, throat, eyes and skin. In epidemiological studies in Europe and North America the health of freshwater swimmers has been compared with that of non-swimmers at the same location. The results are not conclusive but suggest that freshwater swimmers tend to report more respiratory, gastroenteritis, ear, eye and skin complaints than do non-swimmers. Factors which increased the risk of contracting disease included a high frequency of bathing, or poor microbiological quality of the water.

7.168 UK studies on the risks of contracting disease through the recreational use of freshwater include work by the Centre for Research into Environment and Health at the University of Wales on canoeists at a number of venues including Holme Pierrepont, Afon, Tryweryn and in British Waterways' canals. The University of Bristol has also carried out research on canoeists and scuba divers. A study, 'Development of microbial standards', is being carried out by the WRc on behalf of the NRA. This has involved an intensive statistical study of microbiological water quality data from the NRA, water supply companies and the Public Health Laboratory Service, and field studies of recreational sites.

7.169 The health risks of a recreational site will depend mainly on its distance from any discharge, the pathogen content of the discharge and the degree of dispersion and dilution it undergoes, and the mortality rate of the pathogens. Because sewage effluent discharges to inland waters normally receive full biological treatment, they often have lower coliform counts than those to coastal waters. Although the concentration of pathogens will be reduced by sewage treatment processes, there is no consistent relationship between the coliform count and the concentration of pathogens. Moreover, different bacteria and viruses vary enormously in their survival time in freshwater though all may survive longer in lake and river sediments. In addition, rivers have less capacity than seas to dilute and disperse contaminants. Indeed treated sewage effluent can represent a high proportion of the flow of many lowland rivers in the summer when water recreation is at its height. Under most circumstances, the rates of loss of viability of micro-organisms in freshwater are substantially lower than those in the seas.

7.170 It is not possible to provide a totally risk free environment for water recreation without creating conditions that would be incompatible with other water uses and the well-being of the biota. The public needs to be aware, however, of the risks to which it might be exposed and reasonable steps must be taken to reduce risks to an acceptable level. WRc considered the advantages and disadvantages of disinfecting sewage effluents before discharge to watercourses. Chlorination of effluents was not favoured because it would be expensive, environmentally damaging and would produce chlorinated organics many of which are toxic or mutagenic. The ability of chlorination to destroy all the viruses in the sewage was also in doubt. Ozonolysis would be even more expensive than chlorination and, though ozone is a better viricide, little is known about the toxicity of the byproducts it produces. Ultra-violet disinfection of effluents has been
used in the USA to destroy bacteria but the effluent has to be fairly clear for the treatment to be effective and its ability to kill viruses is still the subject of research. Nevertheless, there may be some locations where such measures would be justified, at least when sites are being intensively used. The NRA has published interim guidelines for the 1992 bathing season on acceptable methods of effluent disinfection. These favour physical treatment systems, such as microfiltration, ultra-violet treatment and enhanced settlement, which are not thought likely to produce harmful side-effects.

Standards

7.171 In some regions, notably the Thames region of the NRA, inland waters are monitored for microbiological quality but in general we discovered little evidence of systematic monitoring for this purpose. Controls are not normally imposed on the microbial content of discharges to water and river quality standards do not normally refer to microbiological determinands.

Table 7.12
Sampling regimes and faecal coliform standards applied by North American agencies

<table>
<thead>
<tr>
<th>Agency</th>
<th>Regime</th>
<th>Faecal coliform standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toronto Health</td>
<td>Daily</td>
<td>GM&lt;100/100 ml No sample to exceed 400/100 ml</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canadian Federal</td>
<td>5 samples in 30 days (5/30 days)</td>
<td>GM&lt;200 <em>Escherichia coli</em>/100 ml for freshwaters. Faecal coliform bacteria are acceptable alternative if more than 90% of isolates are shown to be <em>E.coli</em>. Beach 'posted' if criterion exceeded, posting removed when conditions satisfactory. Individual provinces may set single-sample upper limit.</td>
</tr>
<tr>
<td>(1991)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US EPA (1976)</td>
<td>5/30 days</td>
<td>GM&lt;200/100 ml &lt;10% only to exceed 400/100 ml</td>
</tr>
<tr>
<td>US EPA draft</td>
<td>&lt;5/30 days</td>
<td>(a) Enterococci GM&lt;33/100ml, upper limit 61/100 ml for designated beach area in 75% of samples</td>
</tr>
<tr>
<td>guidelines (1986)</td>
<td></td>
<td>(b) <em>E. coli</em> GM&lt;126/100ml, upper limit 235/100ml for designated beach area in 75% of samples</td>
</tr>
</tbody>
</table>

GM = geometric mean
7.172 There have been attempts to establish microbiological standards for recreational waters. The EC directive on the quality of bathing water applies to waters in which bathing is either authorised or traditionally practised, and is not expressly concerned with other forms of water recreation. Nevertheless many forms of water recreation include significant contact with water and, in the absence of other legal standards for UK freshwater recreation, the directive provides a baseline. Box 7.21 shows the mandatory and guide microbiological standards in the directive and table 7.12 shows standards which have been applied in Canada and the USA. The International Canoe Federation’s Medicines Committee told us in evidence that it has developed a standard for water appropriate for canoeing which combines a general environmental criterion, namely “water where fish thrive”, with limits for certain microbiological indicators.

7.173 Existing standards for the quality of recreational waters differ with regard to the sampling regime, the indicator bacteria used and the statistical approach to assessing compliance. Comparison of the different standards is not straightforward, but the imperative (mandatory) standard in the EC directive on the quality of bathing water is the least stringent while its guide level is the most stringent.

7.174 The limits set for microbiological standards in the EC directive appear to have no epidemiological basis and must therefore be regarded as precautionary. Some of the standards and guidelines for recreational waters listed in table 7.12 are loosely based on North American epidemiological studies, but the uncertainties attached to these are now well recognised. It is not possible at present to make any judgment regarding either the degree of protection from infectious disease provided by such limits or the extent to which they may be unnecessarily stringent.

7.175 The directive is unsatisfactory in some other respects. Freshwater is subject to contamination from a wide range of bacteria and viruses of animal origin, some of which, like Leptospira interrogans, cause disease in man. The directive does not refer to them. The directive requires sampling for salmonella and enteroviruses only if their presence is suspected or there has been a deterioration in water quality. Until 1990, the practice in the UK has been to examine two samples for enteroviruses in the recognised bathing season (May to September) when the water had failed bacteriologically in the previous year. But enteroviruses can be found in salt water which conforms to bacteriological standards. In addition, rotaviruses, which can cause gastroenteritis, can be found where enteroviruses are absent103,104. In 1990 the NRA examined most bathing waters for viruses at least twice. As understanding grows of the occurrence, infectivity and monitoring of viruses in the aquatic environment, changes will be required in the directive.

7.176 Because some freshwater recreational pursuits involve less water contact than sea-bathing, it would not necessarily be appropriate to adopt the same standards for inland waters as for sea bathing. We therefore recommend that appropriate microbiological standards be developed for freshwaters and that these standards be used in setting statutory water quality objectives for places in which water contact activities are reasonably common. The setting of statutory water quality objectives is discussed further in chapter 4. The research being carried out by WRc and others should assist the development of such standards by establishing the degree of risk for the main water contact sports and recreations. Meanwhile we recommend that the regulatory authorities, in conjunction with the owners and managers of inland waters, should identify sites used intensively or on an organised basis for bathing and other sports and recreations which involve significant contact with water. We also recommend that the microbiological quality of these waters should be monitored, the results of the monitoring entered in public registers and the public made aware of any cases where EC standards are not achieved. Similarly, when improved standards have been developed for freshwaters, the public should be informed of any failure to achieve them. If monitoring were to indicate persistent failure, action would be needed to relocate facilities or remedy the source of pollution. The latter may include, for example, investment to restrict storm water discharges or disinfection or diversion of sewage effluents.
CHAPTER 8
ECONOMIC INSTRUMENTS

Economic analysis of pollution

8.1 The pollution of freshwater can cause harm to human health, to ecological systems and to public amenity. The prevention of pollution therefore provides benefits to society. However, the implementation of policies to improve water quality imposes costs. Water companies in England and Wales, for example, will have to spend more than £7 billion over the years 1989 to 1995 to improve discharges from sewage treatment works and storm overflows. It is essential, therefore, to analyse the costs of policies to reduce pollution in relation to their benefits. Policies which are efficient—in the sense that they lead to larger improvements in environmental quality, for a given expenditure of public and private resources, than alternative policies—make further environmental improvements possible. Economic analysis helps to illuminate the principles of environmental policy.

8.2 Practical decisions about pollution are influenced, explicitly or implicitly, by evaluations of costs and benefits. Policies which require public expenditure are usually subject to budgetary scrutiny. Policies which require private expenditure—such as the implementation of regulations which restrict permitted effluents—are evaluated (and sometimes opposed) by those who must incur the costs. Other costs are not reflected in actual expenditure: for example, the cost of there being no birds to see as one walks beside a lake. But individuals take account of these costs in deciding whether to oppose specific pollution policies. The economic analysis of costs and benefits provides 'a consistent procedure for evaluating decisions in terms of their consequences', and thereby for choosing efficient environmental policies.

8.3 Cost-benefit analysis might consider, for example, a decision to reduce the level of a pollutant in a body of water. The pollution control authority would evaluate different water quality objectives, and different policies for achieving these objectives. In a simple exercise, it could estimate costs in three different ways. The first (Cost 1) would be the cost of the pollution itself—equivalent to the benefits foregone because of it. Thus if pollution is not reduced, people's walks might be less enjoyable, recreational enterprises might not be established around the waterbody, or there might be irreversible changes in local flora and fauna. The second (Cost 2) would be the cost of reducing pollution by the technique of prevention: the cost to enterprises (and households) of reducing those activities which result in discharge of the pollutants to the waterbody. The third (Cost 3) would be the cost of reducing the pollution by the alternative technique of treatment: the cost to the pollution control authority of achieving the same reduction by treating the water to remove or neutralise the pollutant. There is no reason, in general, to suppose that Costs 1, 2 and 3 will be the same. They will almost certainly be borne by different groups of people. Each of the estimates, in a thorough analysis, would include indirect as well as direct costs; for example, the costs of water treatment incurred by public authorities, the costs to households of having new water treatment facilities built in the vicinity, and the costs to enterprises of shortages of appropriate skills. The costs should also include increased pollution of other sorts if effluent were disposed of to land or air rather than water, and even costs of preparing cost/benefit analyses. The implications of borrowing or raising taxes should not be ignored in a full appraisal.

8.4 The pollution control authority, in an ideal system, would adopt those policies whose implementation involved costs which, when fully evaluated, were smaller than their benefits. If Cost 2 or Cost 3 were less than Cost 1, in the example above, then it would decide to reduce pollution by the cheaper of the two techniques (or by the cheapest combination). The result, under certain special circumstances, and if the policy were pursued fully, is that society would end up with what the Royal Commission Minority Report in 1972 called the 'optimum amount of
pollution: for each pollutant, that level at which the marginal cost of reducing pollution becomes just greater, for society as a whole, than the marginal benefit of the reduction. We will see later that the practical problems in arriving at such a result are dauntingly difficult. The concept of an ‘optimum amount’ of pollution (which has been central to the economic analysis of social costs for more than 30 years) can itself be criticised, as will be seen in paragraph 8.11. Yet the objective of evaluating the costs and benefits of different policies remains of essential importance.

8.5 Environmental policies pose many problems for cost/benefit analysis. There are few accepted standards for studies. Analysts often neglect distributional effects, that is, the impact of policies on different individuals and groups in society. In addition, they have great difficulty in assigning values to benefits such as nature preservation, which in Robert Dorfman's words 'have no natural monetary values'; they pay little attention to uncertainty; they treat the costs of achieving standards superficially and consider too few alternative policies; they assume that policies will be executed with full efficiency. But similar problems would arise in any systematic effort to evaluate the costs of environmental policies. Some such effort is, however, an essential component of environmental improvement.

8.6 The use of market mechanisms to control pollution is a particular case of the application of economic analysis to environmental policy. The principal mechanisms—which include charges on pollution discharged, and permits to discharge pollutants—are discussed in reports prepared for the Commission. Charges establish the price to be paid for pollution, and allow the market to determine the total quantity of pollution; permits ration the total quantity, and allow the market to determine the price. A thorough economic analysis of alternative pollution control policies, it is suggested in these reports, would show that such mechanisms constitute the most efficient (or least costly) instruments for achieving desired environmental standards. They permit flexibility in compliance, so that firms with low costs of controlling pollution make relatively greater reductions in pollution than firms with high costs. Because the level of charges (or the quantity of permits) is established on the basis of benefits to be achieved, pollution can also be reduced most in those places where it does most damage. If a unit of effluent has no known effect on wildlife when discharged into a fast-flowing river but does significant damage when discharged into a sluggish river, then reductions in effluent at the latter are more 'cost-effective', all other things being equal, than reductions at the former.

**BOX 8.1 SOME TERMINOLOGY**

1. **TRADEABLE PERMITS** - Permits to discharge which may be bought and sold.
   - i) Granted tradeable permits - tradeable permits which are initially allocated freely, probably on the basis of existing consent (sometimes referred to as grandfathered or free tradeable permits).
   - ii) Auctioned tradeable permits - tradeable permits which are allocated initially by auction.

2. **EFFLUENT OR POLLUTION CHARGE** - A charge levied on discharges relating to the polluting load of the effluent (sometimes referred to as an effluent tax or levy).
   - i) Cost recovery charge - a charge designed to cover the costs to the pollution control authority of operating regulatory controls (does not cover the environmental costs of discharges).
   - ii) Incentive charge - an effluent or pollution charge designed to persuade the discharger to reduce pollution. Generally set at a higher level than i).

3. **MARGINAL ABATEMENT COST** - The cost to the discharger of reducing the discharge by one more unit of pollution (defined for example by 1 kg of BOD/day).

4. **ECONOMIES OF SCALE** - The case where, as a firm's total output increases, the average cost per unit output falls.
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8.7 Market mechanisms such as charges and auctioned permits have the further advantage that they make harmful activities more expensive. This gives 'producers and consumers clear signals about the costs of using environmental resources'. Some policies to control pollution by using economic instruments may also provide extra revenue to public authorities: they may yield more in new revenue than they cost to administer. These revenues could in turn be used to finance further investments in environmental improvement, as will be discussed later. But they could also be seen as a generally efficient form of taxation, in the sense that the activities which are subject to tax — and thus to discouragement — are themselves harmful. The overall additional benefit of the policy (to all members of society) should however be equal to its overall additional costs.

8.8 The use of market mechanisms in environmental policy has been discussed fairly intensively since the early 1970s, at least during successive cyclical upturns in political interest in environmental pollution. There is considerable experience of charging schemes in France, Germany and the Netherlands, which we discuss in paragraphs 8.24–8.39, and of tradeable permit schemes in the United States. Even in the former Soviet Union, the 'ecological reformation of the economy' of 1987 included 'the introduction of financial incentives for natural resource conservation and on levels of pollution emissions'. Starting in 1991, enterprises were to pay pollution fees, charged 'for standardized air or water pollutant emissions, and for waste storage as well as fines levied for exceeding the established standards'.

8.9 There has been rather little international interest, nonetheless, in adopting a comprehensive economic approach to pollution, in which market mechanisms provide some sort of alternative to environmental regulation. This may in part reflect a reasonable scepticism about the larger claims made for deregulation. The use of market mechanisms in environmental policy should indeed be seen as a form of regulation, and not as an alternative to it. Charges and permit schemes require new regulations—for example, to restrict discharge of pollutants without paying a charge or obtaining a permit, or to create new property rights—and new administrative activities. An essential element of the economic approach must be to include a systematic analysis of the costs and benefits associated with alternative regulation policies. In different circumstances, such analysis might favour regulation by permits, or by charges, or by uniform discharge standards.

8.10 Even the more limited claims for market mechanisms have, however, received surprisingly little support in the United Kingdom and elsewhere. The economic arguments have remained strong but contrary political arguments have prevailed. The point made by the Royal Commission majority in 1972—that, in the absence of regulatory limits, pollution charges allow people to 'pay the charge and discharge without limitation'—has been central to these political arguments. Pollution control authorities have been reluctant to relinquish physical limits on discharges of pollutants, even when alternative policies seem likely to lead to significant reductions in the costs of preventing pollution—a point that we discuss further in paragraph 8.22.

8.11 Such concerns reflect serious conceptual difficulties for environmental policy. The Royal Commission's definition of pollution refers to hazards, harm, damage, and interference. But if to pollute is to cause harm, then the concept of an optimum amount of pollution is unavoidably troublesome. It is coherent only in the context of the analysis of a whole range of public decisions, in which the harm caused by a certain amount of pollution needs to be compared with the harm which would be caused if resources were diverted from other important purposes, not connected with pollution (and seldom within the control of the pollution control authorities). Public policy might thus compare the harm caused by a small reduction in oxygen levels in a river—for example, reducing the number and diversity of fish—with the harm which would be caused if fewer resources were available for other desirable objectives, such as providing infant and nursery care. To attempt to impose very strict limits on pollution risks diverting scarce resources from activities which might be valued much more highly by society than the elimination of a marginal unit of pollution.

8.12 The measurement of environmental benefits has been the subject of intense recent study. Evaluation surveys now attempt to elicit how much people would be willing to pay for beautiful views (and even for the knowledge that other people have beautiful views). But the measurement problems remain considerable. It is relatively easy to think about how much one
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would pay for the sorts of services—like visits to a lake with good quality water for swimming—which have close market substitutes. It is much less easy when the 'services' are indivisible, such as distant views of a lake. One does not usually think about how much one would pay for Windermere to be unspoilt, any more than one thinks about how much one would pay for the conservation of the Royal Navy. In the example of swimming, people are more like consumers; in the example of an unspoilt lake, they are more like citizens. But the respondents in environmental benefit surveys are citizens as well as consumers. A citizen might influence water policy by voting for a party which promises to preserve Windermere, for example, or by joining a conservation organisation, or by stating a willingness to pay heavily for walks around lakes, or by expressing an opinion about the use of environmental benefit surveys. It is important to note too that policy decisions, such as to establish uniform permitted levels of pollution, themselves influence subjective valuations of environmental benefits. People do not have time, for example, to study the scientific basis of all environmental directives, and must devise some sort of algorithm or shortcut for their own decision-making. They might thus be willing to pay large amounts of money to prevent the level of nitrate in water from exceeding European Community limits. They might pay much less, perhaps, to prevent certain specific risks associated with nitrate in water.

8.13 The problems of evaluating benefits and therefore of balancing costs and benefits at the margin are so great that the relevant authorities usually specify the desirable environmental standards that they wish to be attained. The costs of achieving these standards are often not directly considered by them, although they may not normally attempt to set standards for which the costs of compliance are clearly very high, especially if immediate compliance is required. It is interesting in this connection that the pollution inspectorate in England and Wales normally takes into account the costs involved in arriving at BATNEEC solutions, in that it is prepared on occasions to allow firms several years' grace in order to achieve full compliance.

8.14 The continuing integration of European environmental regulations makes the need to estimate the costs and benefits of implementing these regulations particularly urgent. Community-wide water directives, for example, are dauntingly difficult subjects for full-scale cost-benefit analysis, given the enormous variations in physical conditions and valuations of benefits. But the systematic incorporation of economic considerations into Community environmental decision-taking is correspondingly important. The higher the standards that the Community attempts to set, the higher the costs of compliance are likely to be, and the greater the potential for conflict between environmental objectives and other desirable objectives of society.

8.15 The use of economic analysis, including the appropriate use of economic instruments, is in our view an essential component of effective policies to reduce pollution. Although we are a Royal Commission on Environmental Pollution, we cannot consider pollution as though it were the only problem confronting our society. The cost of reducing pollution must be weighed against the costs of attempting to remedy other social problems. This effort is greatly facilitated by systematic economic analysis. The economists' conception of an 'optimum amount of pollution' can, however, be seen as unattractive and even inconsistent, as was noted earlier. This reflects a tension between two different ways of looking at the economics of pollution, corresponding to the perspectives of efficiency and of equity.

8.16 If it is assumed that the 'economic problem', in relation to environmental harm, 'is to maximise the value of production' then it is not unreasonable to speak of optimum pollution. But for anyone concerned with policy, this is not, of course, the only objective. To judge the effects of pollution exclusively in terms of, for example, 'the value of the fish lost' versus 'the value of the product which the contamination of the stream makes possible' is to ignore essential aspects of policy concerned with equity. The person who contaminates a stream (person A) harms another person (person B) who hoped to use the stream; he harms the fish; he may harm future people, unknown or even unborn, who might have used the stream in the distant future. Under certain circumstances, the most efficient solution may be attained if person B pays person A to stop polluting the stream. But the solution is most unlikely to be equitable, and equity, too, is a component of policy choice.
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8.17 Pollution charging schemes should be efficient, and they also have the advantage from the perspective of equity, noted by the Royal Commission minority in 1972, that they are a 'means of making the polluter pay for the damage done by his pollution'\textsuperscript{14}. They thus reinforce the widely accepted objective of implementing the 'polluter pays' principle. This principle is not always easy to interpret. There are many kinds of harm, including but not confined to environmental pollution, which people impose on others, without being expected to pay. Sometimes the harm is so minor that it is not worth requiring (or requesting) payment; sometimes the harm is not recognised as such under current legislation; sometimes the person imposing the harm cannot reasonably be expected to have foreseen the effects of his actions; sometimes the harm results from the cumulative actions of a large number of persons. We cannot therefore, as a Commission concerned with environmental pollution, recommend that all polluters should always pay for all the harm they do. But we do consider that charging schemes represent a practical way of making producers and consumers more aware of the cost imposed by water pollution; we look in chapter 9 at other, complementary measures, including proposals for public reporting of the 'output' of certain pollutants. Charging schemes should, however, help to make possible progressive reductions in pollution over a long period and an eventual transition to conditions in which acceptable levels of pollution are both low and declining.

Some case studies

8.18 There is an extensive literature on the theory of market mechanisms in the environmental context. We asked London Economics to provide a paper giving a general overview of the scope for applying market mechanisms for the control of water pollution\textsuperscript{15}. It compared charges and tradeable permits as substitutes for traditional regulatory approaches to controlling water pollution. In order to look more closely at how market mechanisms might work in practice, we commissioned Stirling University and Mr J Pezzey to report on how a range of market mechanisms might operate in order to control a single measure of pollution, BOD, in the Forth Estuary\textsuperscript{16}. This work built on research carried out by the University with support from the Economic and Social Research Council (ESRC). We also considered the study by Newcastle University\textsuperscript{17} into the feasibility of a charging scheme designed to control pollution in the Tees Estuary. This work was commissioned by the Government in 1974 as part of its response to the Royal Commission's Third Report. Rivers and estuaries differ in a number of ways, in particular in their ability to disperse pollutants; we felt that nonetheless these reports provided valuable insights into how market mechanisms might operate in freshwater systems.

8.19 The Tees study is described briefly in box 8.2. It investigated how a charging scheme might be used instead of the statutory system of discharge consents to achieve target water quality standards in an estuary which was, at the time of the study, grossly polluted with industrial effluents and raw sewage. The study indicated that such a scheme would be very complex with charges varying substantially along the estuary for each pollutant. In addition, the calculations depended on the validity of several assumptions. It was assumed that dischargers were not able to take advantage of economies of scale when investing in pollution abatement; that no discharger dominated discharges to the estuary; and that dischargers acted to minimise their costs. Since these assumptions did not hold good for sewerage undertakers, who had considerable scope for economies of scale, sewage treatment works were not covered by the proposed charging scheme. Moreover, the charging scheme required the authorities to have access to substantial quantities of information about the costs of investment options available to dischargers — information that, in practice, is not likely to be generally available. The study also considered the effect of certain simplified charging schemes, requiring only limited information from dischargers. Making the same assumptions as described above, it was concluded that, in economic terms, such schemes could be more efficient at improving river quality than an inflexible application of regulatory controls. They would not, however, ensure that target water quality standards were achieved.

8.20 Box 8.3 contains a brief description of the Stirling/Pezzey report. It indicates that charging schemes and systems of tradeable permits would be complex if they were to achieve quality standards for BOD. The paper by London Economics put forward a strongly argued case for the use of tradeable permits. It is sometimes argued that, under such schemes, monopolistic factors
In 1974, the Government commissioned a three-year study to investigate how a charging scheme might be used, in place of a system of discharge consents, to enable the Tees estuary to meet in a specified timescale certain water quality objectives. Three water quality objectives were considered:

- The maintenance of the then water quality of the Tees with minimum additional treatment to remove aesthetic nuisance, gross discolouration and smell;
- The improvement to and maintenance of a water quality conducive to the existence of a limited coarse fish life in the estuary;
- The improvement to and maintenance of a water quality conducive to the passage of migratory fish through the estuary.

A water quality model of the estuary, developed and made available by ICI, was used to relate certain parameters (dissolved oxygen, ammonia and cyanide) in 0.3 mile sections, to input and persistence of pollutants and the tidal flows of the water. Another model calculated the investment programme which would achieve the water quality levels in the estuary by target dates at lowest cost, using unpublished information obtained from the major dischargers on the costs of abating their discharges. A third model calculated a unit charge for discharges of each pollutant into each section of river which would induce the dischargers to undertake the least cost investment programme.

The model assumed that there were no economies of scale available to dischargers, that there were no dominant dischargers in the estuary and that dischargers would always act to minimise their annualised total costs. Since these assumptions did not hold good for sewerage undertakers, sewage treatment works were dealt with separately, outside the optimising model.

Some of the conclusions reached by the study were:

- **Within** the assumptions built into the model, a charging scheme could be devised which would persuade dischargers to undertake pollution control measures very close to the lowest cost abatement programme.

- Depending on the target quality objective, investments were required with an annualised cost to the dischargers of £11m–£21m at 1976 prices (about £40m–£72m at 1990 market prices). In addition, the charges paid by the dischargers for their remaining discharges would amount to £13m–£16m pa (about £44m–£57m at 1990 prices).

- The cost of investment in pollution abatement increased (sometimes sharply) with the level of water quality aimed for and, in general, the shorter the timescale for achieving the water quality targets the higher the cost (although this was only a significant factor for about 6 years).

- Location was an important factor. Large variation in unit charges along the estuary were required to secure achievement of least cost investment programmes. Charges for some pollutants might need to vary by orders of magnitude.

- Sensitivity of investment programmes to the unit charge varied: some abatement procedures consisted of large numbers of discrete investment options and small variations in unit charges at some levels might introduce or exclude such investments altogether. Conversely, large variations at other levels would have a limited impact.

A high level of information about investment options and their costs was required by the study. Some of it was commercially sensitive and was only obtainable with the good will of the major dischargers on the Tees. In recognition that this level of information was unlikely to be available in other circumstances, simplified charging schemes using only limited information were considered. Making similar assumptions to those described above, the study concluded such schemes could come within 10%–40% of the least cost solution. This was a closer outcome than was obtained by some simplified regulatory options considered by the study but none of the simplified charging schemes would ensure achievement of water quality standards throughout the estuary.
BOX 8.3 THE REPORT ON THE FORTH ESTUARY

The study by Stirling University considered seven options for achieving certain targets of oxygen levels:

- uniform percentage reductions in BOD by each discharger (to be achieved through regulation);
- flexible regulation, whereby the control authority would impose different reductions on dischargers based on its assessment of the scope and cost of reductions in each case;
- auctioned tradeable permits;
- granted tradeable permits;
- incentive charges;
- charge-subsidies, whereby the discharger pays a charge when effluent exceeds a baseline level and receives a payment from the authorities when the effluent falls below the baseline;
- subsidies paid to dischargers for reductions in effluent.

As in the Tees study (box 8.2) a water quality model was used to predict the impact of polluting inputs on the receiving water. In this case only one measure of pollution, BOD, and one measure of water quality, the dissolved oxygen level, were considered. Again as with the Tees study, another model calculated the investment in pollution abatement which would achieve at least cost the target oxygen level along the estuary by target dates. In order to do this, information was obtained from the major dischargers on the costs of their investment options. A third model calculated the unit charges and subsidies required to induce dischargers to carry out the least cost investment programme, under similar assumptions to those described in box 8.2 on the Tees study. The same model calculated the prices at which permits would be traded.

Some of the findings of the study were:

- Uniform percentage reduction was the most costly method of achieving the target oxygen levels;
- Flexible regulation might achieve the least cost investment programme, provided the control authority had access to a high level of information on the dischargers’ costs.
- Tradeable permit systems could achieve the least cost investment programme if the markets were competitive. However, with just two dischargers accounting for over 50% of BOD emissions, non-competitive behaviour might emerge. In addition some firms might hoard permits for strategic reasons.
- Charging and subsidy schemes could come close to the least cost investment programme if sewage treatment works were excluded and the assumptions required by the model (eg no dominant dischargers and cost minimising behaviour) were valid. A high level of information on dischargers’ costs was required to set the charges.
- All the pure market mechanisms would be complex and expensive to administer but would still offer cost advantages over uniform percentage reductions.
- Market mechanisms did not offer significant cost advantages over flexible regulation, in part due to factors peculiar to this study. As a consequence of this, the extra administrative costs of introducing market mechanisms might be significant in relation to the potential savings when compared to the cost of flexible regulation.
- The cost to dischargers of meeting the target oxygen levels was generally lower if the timescale was five years rather than one year.

might lead to distortions from the optimal outcome. London Economics considered that these effects might be slight and that, even in a limited market, tradeable permits could offer worthwhile reductions in the cost of attaining water quality standards. The report by Stirling University, however, suggested that the limited size of the market for trading in BOD permits on the Forth might significantly reduce there the benefit of such a scheme. The system would also require the regulators to have access to a reliable water quality model to enable them to ensure that trades would not have an adverse impact on river quality.

8.21 The Forth study also indicated that a flexible application of traditional regulations could be an economically efficient method of controlling BOD if the regulators had sufficient
information on the cost to dischargers of pollution abatement. Both the Tees and the Forth studies found that the costs to dischargers of reducing pollution were less if more time were allowed for achieving improvements, though the Tees Study, which looked at a longer timescale, found that costs stopped decreasing beyond a period of six years.

8.22 The Tees and the Forth studies lead us to conclude that a charging scheme operating by itself could not provide a satisfactory method of achieving water quality standards. The degree of commercial information required by the authorities, the need for complex economic and environmental models and their reliance on uncertain assumptions about the behaviour of dischargers in response to cost pressures provide powerful reasons for caution. For example, firms do not necessarily behave in a simple cost-minimising fashion. The achievement of WQSs is a fundamental and long standing principle of UK water pollution control. It would, in our view, be unacceptable to introduce a system of market mechanisms which did not provide at least as much confidence that WQSs would be achieved as the present system of regulation. Nor would it be acceptable to rely on a control system which could not ensure compliance with EC obligations. The work that we commissioned indicates that tradeable permits backed by a complex trade-approvals structure might offer the necessary certainty of achievement of WQSs but, in the case of point discharges to freshwaters, we consider that the scope for trading would be limited because of the importance of locational effects and the dominance of STWs as the main sources of discharges. We therefore doubt whether tradeable permits would be a practicable option in this context.

8.23 We therefore conclude that, for point discharges into freshwater, economic instruments by themselves do not offer an acceptable approach and that more traditional forms of regulation, operating with due flexibility, must remain in place to ensure the achievement of WQSs. The role of any market mechanism should therefore be to reinforce the regulatory system to ensure that it works as cost-effectively as possible and the choice should fall on a mechanism which could stand alongside a traditional regulation-based system. We consider that a charging scheme would be more suited than tradeable permits to fulfilling this function in the context of point discharges to freshwater, although we recognise that tradeable permits might be appropriate in other contexts.

Some charging schemes in practice

8.24 Charging schemes operate alongside a system of discharge permits in Germany, France and the Netherlands. In all three countries the schemes cover point source discharges to water. The German scheme also has a charge for certain types of surface water run-off. These schemes provide examples not only of how charging schemes operate in practice but also of how such schemes can differ to suit local circumstances. They are described in paragraphs 8.25–8.37 below and a more detailed explanation of the German scheme is given in appendix 7. Spain and Italy also have the necessary legislative framework and Spanish charges are expected to raise £2.7 billion over 10 years, to be spent on cleaning up rivers. The NRA and the Scottish river purification authorities have recently introduced charging schemes to recover the costs they incur in monitoring discharges. These British schemes are discussed in paragraphs 8.41–8.43 below.

Pollution charges in Germany

8.25 Legislation to establish the German charging scheme was enacted (in the former Federal Republic) in 1976 and charges were first levied in 1981. A report by WRc in 1990 stated that the objectives underlying the introduction of the scheme were:

a. to provide an economic incentive to waste water dischargers to improve the quality of their effluents;

b. to encourage existing dischargers to adopt the technology standards required of new plants (see paragraph 8.28);

c. to be consistent with the polluter pays principle;

d. to recover the costs of environmental pollution control;

e. to provide funds for preserving or improving the quality of the aquatic environment, including research and development.
8.26 The charge is levied by the Länder (states) on all industries and municipalities which discharge directly into lakes, rivers, the sea or groundwater used for drinking. Spills and diffuse sources are not charged under the scheme but there is a charge for run-off from areas owned by local authorities. The charge, which is based on the number of 'units' of pollution discharged, is related to the volume and content of the effluent (see box 8.4). Both the formula used to calculate the charge and the parameters covered are set at federal level and are the same for all Länder. Most Länder calculate the charge on the basis of content and levels of effluent specified in discharge consents. To obtain a reduction in charges, the discharger has to ask for a lower consent. This is then used for calculating the charge but also for assessing excess charges (see paragraph 8.29). Threshold values below which no charges are levied are set both in terms of minimum concentrations and total annual load.

8.27 The scheme was implemented gradually. Five years after the enabling legislation had been passed the charges were introduced at DM 12/unit which rose in annual predetermined steps to DM 40/unit in 1986. In 1990, the level was revised again, to DM 50/unit from 1 January 1991 and will increase in biennial steps to DM 90/unit by 1 January 1999.

**BOX 8.4 THE GERMAN CHARGING SCHEME**

The pollutants covered by the system are:
- chemical oxygen demand (COD);
- phosphorus;
- nitrogen;
- organic halogen compounds as adsorbable on activated carbon (AOX);
- several metals and their compounds (mercury, cadmium, chromium, nickel, lead, copper);
- substances toxic to fish.

A unit of each of these pollutants is charged at the same rate but the definition of a unit varies for each pollutant. For example, for COD the unit of pollution is 50 kg, for mercury the unit is 20 g and for copper 1000 g. Threshold values are given in the waste water charge law, both in terms of minimum concentration and total annual load which must both be exceeded before charges are levied. The threshold values for COD for example, are 20 mg/l and 250 kg/annum. The law also lays down the analytical methods to be used.

8.28 A number of features of the scheme are designed to enhance the incentive to dischargers to improve the quality of their effluent. For example, if a discharger submits plans for the installation of an effluent treatment plant the reduction in the charge that this investment will produce is granted for a period of three years prior to the date of commissioning the new plant, provided that the reduction in load is at least 20%. If the plant is not installed or fails to meet its target performance then the discharger must pay back any unjustified reductions. Dischargers also receive 75% reductions in their charges if their treatment plants meet federally defined effluent standards (these standards are compulsory for new discharges but the timing of their imposition on existing dischargers is at the discretion of local regulatory authorities). These latter reductions are now time limited, falling to 40% after 4 years and 20% after a further 4 years. However, if the federal standards are subsequently tightened and the effluent meets the new standards, the charges are again reduced by 75%. This is intended to encourage further development of improved treatment technology.

8.29 Direct discharges are self-monitored—the dischargers themselves collect and analyse the samples, sending the results to the regulatory authority. Compliance samples, collected and analysed by the regulatory authority, are taken at ad hoc intervals. The latter are used to ensure that the self-monitoring is reliable, that the consent is met and, if necessary, for prosecution. For the calculation of excess charges, a rolling series of five samples taken by the regulatory authorities is used. If one of the five exceeds the permitted value by 100% or more, the units are
increased by half of the percentage excess. If more than one exceeds the permitted level by 100% or more, the units are increased by the full amount of the percentage excess of the highest level found.

8.30 The revenue raised from the charging scheme is collected by the Länder who are required under the Act to use the funds to improve or maintain the quality of the aquatic environment. This includes contributing towards the cost of pollution control measures undertaken both by municipalities and by private industry and the costs of administering the system. For example, funds can be applied to the provision of new or upgraded sewage works for towns and villages. The Act specifies the measures which may be funded by the revenue derived from the charges (see appendix 7).

8.31 When we visited the Federal Republic of Germany in 1989, we were told by the Agency for Water and Waste (Landesamt für Wasser und Abfall) in North Rhine Westphalia that the level of the charge, though in general less than the cost of treating discharges (estimated to be about DM 150 per unit of pollution), was nevertheless large enough to provide firms with an incentive to reduce their discharges.

8.32 A report by Environmental Resources Ltd (ERL) published in 1990 suggested that the German charging scheme had contributed to a significant reduction in pollution from oxygen depleting substances, especially from local authorities which operate sewage treatment works. The study reported that there was a large incentive impact immediately prior to implementation and that the subsidies offered under the scheme were considered to encourage investment. The German Industry Association (Der Bundesverband der Deutschen Industrie) is reported in the study by WRc to consider that, taken as a whole, the system is reasonably fair and is becoming effective as the charges are systematically raised. The German charge is now considered to be comparable in level to the Dutch charge, described in box 8.6.

Pollution charges in France

8.33 The French scheme (see box 8.5) was introduced in 1974 and is levied by the six Agences Financières de Bassin (River Basin Funding Agencies) on industry and municipalities. The primary objective of the system is revenue-raising to finance improvements in water quality through investment in treatment facilities.

8.34 According to ERL's study, the French charges are low in comparison with the Dutch and German charges and are generally considered unlikely to act as an incentive to invest in pollution control equipment. ERL also reports that there has, however, been improvement in investment in water treatment facilities, both by industry and by local authorities, and the scheme is considered successful by the French authorities in raising revenue for water treatment purposes.

Pollution charges in the Netherlands

8.35 The water charging scheme was introduced in the Netherlands in 1970 under the Surface Water Pollution Act 1969 (Wet Verontreiniging Oppervlaktewateren). Charges are levied and collected by the State for discharges to state waters, which include major rivers and territorial waters. For other surface waters, the responsibility for the setting and collection of charges lies with the regional authorities but has, in all but three cases, been delegated to water boards.

8.36 The revenues from the state charges are used to grant money to dischargers to alleviate specific pollution problems. This mainly comprises grant aid for sewage treatment plants and for industrial waste water treatment equipment of industries discharging into state-managed waters. The total annual revenue from this charging scheme is of the order of £35 million; approximately £600 million has been given in grant aid since 1970. The revenues from charges levied by the
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**BOX 8.5 THE FRENCH CHARGING SCHEME**

The charges are based on the level of discharge in terms of volume per day. The charge formula varies between the different Agences de Bassin. The parameters used for the formulae are:

- suspended solids;
- soluble salts;
- oxygen demand (includes both COD and BOD);
- toxic matter;
- nitrogen;
- phosphorus (organic plus inorganic).

There are national standards for the measurement of these parameters. However, not all Agences de Bassin levy charges on nitrogen and phosphorus.

There is no formal link between the discharge permit system and the pollution charges. The charges are not levied on the basis of permitted discharges but are calculated by formulae which contain coefficients calculated on an industry by industry basis.

The French charging rates are reviewed annually.

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**BOX 8.6 THE DUTCH POLLUTION CHARGES**

Charges are levied on the basis of population equivalent (pe) loads (1 pe equals the amount of oxidisable material produced by one person per day). Domestic discharges and small industrial discharges (producing effluent below 5 pe) pay a standard charge. Charges for medium sized firms (producing effluent below 1000 pe) are assessed on the basis of tables of pre-determined coefficients (formulae agreed on an industry by industry basis) with the option of direct measurement. Charges for large firms (discharging over 1000 pe) are on the basis of direct measurement.

A basic standard formula is used. The parameters included are:

- COD;
- nitrogen (organic nitrogen plus ammoniacal nitrogen).

The formula may be varied to include heavy metals and an extension of the charges to phosphorus is being considered.

The state charge is uniform throughout the country but has different charging rates for salt and fresh waters. The state charges are generally lower than charges made for non-state waters, which vary widely, with each responsible authority having discretion over the level of charge per population equivalent.

In 1990 the levy for discharges into state managed waters was £11/pe for discharges into freshwater and £9/pe for discharges into sea water; for 1995 a £7 rise is expected because of additional costs for example for phosphate removal. Levies for discharges into non-state waters varied in 1990 from £11/pe to £35/pe.

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water boards or provinces are used to fund their water quality management costs (this includes the operational costs of sewage treatment). Everyone discharging oxygen consuming substances into the sewer system or into non-state waters has to pay a charge. The annual revenue from this levy amounts to £400 million at present.
8.37 Dutch government officials told us that pollution charges in the Netherlands were successful in providing an incentive for firms to reduce their discharges. A number of studies have also suggested that the Dutch system has been successful both in its revenue raising aim and in improving water quality. A study in 1988 indicated that for nearly 60% of the companies interviewed, the pollution charge was the decisive factor in the decision to increase abatement measures and that the high level of the charge was important. The level of charge rose sharply in the 1970s and in 1980. The relatively high level of charges has resulted in the system having an incentive effect, with improvements in water quality being particularly marked in regions with higher levels of charges.

Lessons from these schemes

8.38 The French, German and Dutch experiences of charging schemes provide useful examples of how such schemes can operate alongside more traditional regulation in the context of fresh water. They demonstrate that incentive charging schemes are a practicable option and that a scheme which is introduced gradually may still have a marked impact on dischargers' behaviour prior to full implementation (paragraph 8.32). If charges are set at a low level, they may be successful in raising revenue for investment in effluent treatment but they may provide little direct incentive for dischargers to improve their effluent quality (paragraph 8.34). If set high enough, however, and combined with grants for investment, charges can influence dischargers' behaviour even though they may remain below the marginal cost to most firms of pollution abatement technology (paragraphs 8.31 and 8.37).

8.39 Although the schemes provide useful guidance, any charging scheme in this country would need to be tailored to British circumstances. In particular, the absence of comprehensive, nationally defined effluent emission standards for all types of discharges, on the German model, or of industry-based coefficients, as in France and the Netherlands, needs to be taken into account. The reliance in Britain on water quality standards as the foundation for the control of discharges is also an important factor.

Charging schemes already operating in the UK

Trade effluent charges

8.40 For many years firms in Britain have paid trade effluent charges in respect of their discharges to the public sewerage system (the system of consents for discharging to sewer is described in chapter 7 in box 7.1). The charging system is described in box 8.7. It is based on the.

<table>
<thead>
<tr>
<th>BOX 8.7 TRADE EFFLUENT CHARGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade effluent charges are intended to recover the costs incurred in treatment and disposal of trade effluent on the basis of estimates of relevant expenditure. Increases in trade effluent charges in England &amp; Wales are subject to OPWAT's control.</td>
</tr>
<tr>
<td>Trade effluent charges are based on a nationally agreed formula and include elements for COD and suspended solids but not for other contaminants such as heavy metals, although these may be the subject of control through conditions on the discharge consent. The charges are related to volume and load. Charges cover the reception and conveyance of effluent, and the primary treatment cost. The formula compares the strength of the discharge (in terms of COD and suspended solids) to that of ordinary sewage and dischargers are charged only the treatment costs for the extra strength of the sewage. For example, if a trader discharges effluent with three times the suspended solids level of ordinary sewage, the charge will be the cost of treating the discharge minus the cost of treating the same amount of ordinary sewage, amounting, in this case, to twice the cost of treating ordinary sewage. Where discharges are relatively small in quantity or weak in strength an annual minimum charge is set.</td>
</tr>
</tbody>
</table>

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volume and strength of the effluent and is intended to cover the cost to the sewerage undertaker of dealing with the discharge, as compared to dealing with ordinary sewage. Two studies on industrial responses to trade effluent charges\textsuperscript{27,28} and preliminary results of a draft study for the NRA on responses to abstraction charges\textsuperscript{29} show that firms may not behave in a simple cost minimising fashion. Some firms were aware of the charges and their options for reducing them but many lacked the necessary knowledge or were inhibited by internal procedures. Despite charges rising 400\% over 5 years for some companies they failed to use available technology to reduce emissions, which could have rapidly repaid the investment. Capital availability and procedures for authorising investment were found to inhibit local managers. Charges, for example, registered as operating expenditure and attracted little head office attention while capital investment required head office approval. Managers may have preferred to use tight capital allocations for projects which increased sales or revenue rather than for cost reductions. Whatever the reason, the findings of the studies reinforce the conclusion in paragraph 8.38 above that charges set at low levels are unlikely to have an incentive effect and indicate that this may apply even in instances where charges exceed the marginal cost of abatement.

Cost recovery charging for discharges into water

8.41 Using its powers under the Water Act 1989, the NRA has introduced a charging scheme for direct discharges to water. The scheme is designed to recover the NRA's costs of determining, issuing and monitoring discharge consents. These costs were previously funded by Government grant. An annual charge is levied, based on the volume and content of the effluent as set in the discharge consent and on the type of receiving water (surface, estuarial, ground or coastal waters). Volume, content and type of receiving waters have been put into bands and a factor assigned to each band which reflects the NRA's costs. The bands are shown in box 8.8. The factors for volume, content and type of receiving water are multiplied together to give the total number of chargeable units. This is then multiplied by the 'unit rate' which is set by the NRA so that the total revenue raised should cover its costs. For the financial year 1991/92 the unit charge was £270 and the total revenue expected to be £25m, rising to £44m in 1994/95\textsuperscript{30}.

8.42 The purpose of the new charges is not to provide an incentive to reduce discharges; it is not within the NRA's present statutory powers to introduce such a scheme. However, within each type of receiving water, charges will be higher for the larger, more polluting discharges than for the smaller, less polluting ones because of the relation of the charge to volume and content. The charges do not reflect the environmental sensitivity of different types of receiving waters. For example, the weighting factor given to groundwater is 0.5 and to estuarial water is 1.5. This reflects the NRA's monitoring costs but has the effect of attaching the lowest charge to the most sensitive water. To the extent that these differences influence the behaviour of dischargers they seem likely to do so in a way which is counterproductive.

8.43 A cost recovery charging system for direct discharges has also been introduced in Scotland. It differs from the NRA's scheme in that the charges paid by individual dischargers are linked more explicitly to the RPAs' monitoring efforts. There are ten schemes, operated by the seven RPBs and three island councils. The schemes vary slightly between the RPAs but are based on a common structure (see box 8.9). No charging scheme has yet been proposed for Northern Ireland.

An incentive charging scheme for the UK

8.44 In paragraph 8.22 we concluded from the Tees study and the work which we commissioned that any charging scheme would have to supplement traditional regulatory controls rather than replace them if water quality standards were to be achieved. The German and Dutch experience demonstrates that a charging scheme operating as a complement to regulatory controls can provide a significant incentive to dischargers to reduce polluting effluents and is a practicable option. The charging schemes described in paragraphs 8.40-8.43, which already operate in the UK, provide some experience which could also contribute to the design of a UK incentive scheme.
**BOX 8.8  CALCULATING THE NRA COST RECOVERY CHARGE FOR DIRECT DISCHARGES**

In October 1990, the NRA introduced the first charge under the scheme for the processing of applications for new or revised consent conditions. The fixed, once only, fee is currently set at £350 with a reduced charge of £50 in respect of certain small discharges.

A further annual charge was introduced from July 1991 and covers the NRA’s expenditure attributable to the control of direct discharges to surface, ground, estuarial and coastal waters, but not any cost of cleaning up pollution or the value of any disbenefit from environmental deterioration. The annual charge is related to the volume and content of the discharge and to the type of receiving water. Chargeable units are calculated as shown below, based on the discharge consent. The rate of charge for each unit in 1991/92 was £270.

Bands are used to calculate chargeable units as follows:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>0.4</td>
</tr>
<tr>
<td>&gt; 5–100</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt; 100–1,000</td>
<td>2.0</td>
</tr>
<tr>
<td>&gt; 1,000–10,000</td>
<td>3.0</td>
</tr>
<tr>
<td>&gt; 10,000–50,000</td>
<td>5.0</td>
</tr>
<tr>
<td>&gt; 50,000–150,000</td>
<td>9.0</td>
</tr>
<tr>
<td>&gt; 150,000</td>
<td>14.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – complex organic, pesticides</td>
<td>15.0</td>
</tr>
<tr>
<td>B – potentially toxic, metals etc</td>
<td>5.0</td>
</tr>
<tr>
<td>C – organic sewage/trade effluent</td>
<td>3.0</td>
</tr>
<tr>
<td>D – general trade effluent</td>
<td>2.0</td>
</tr>
<tr>
<td>E – site drainage</td>
<td>1.0</td>
</tr>
<tr>
<td>F – low environmental effect</td>
<td>0.5</td>
</tr>
<tr>
<td>G – minimal environmental effect</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receiving water</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>0.5</td>
</tr>
<tr>
<td>Coastal</td>
<td>0.8</td>
</tr>
<tr>
<td>Surface</td>
<td>1.0</td>
</tr>
<tr>
<td>Estuarial</td>
<td>1.5</td>
</tr>
</tbody>
</table>

For example, a consent which allows for a daily discharge of 8,000 cubic metres of organic trade effluent into a river:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Content</th>
<th>Receiving Water</th>
<th>Chargeable Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>8,000</td>
<td>C</td>
<td>River</td>
</tr>
<tr>
<td>Factor</td>
<td>3.0</td>
<td>3.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[\text{Chargeable Units} = 9.0 \times \text{Unit Rate} \times \text{Total Charge} = 9.0 \times \£270 = \£2,430\]
The scheme for Scotland has the same two tier structure as the system introduced in England and Wales. A flat fee of £350 is payable for every application for a new or revised consent, with a reduced charge of £50 for certain small discharges.

The second tier comprises an annual charge which aims to recover the costs incurred by the RPAs in monitoring discharges and their environmental effects. Only minor discharges are exempted.

The approach in Scotland links the annual charge more directly to the monitoring actually carried out in respect of each discharge. Initially the charges reflect each RPA's current monitoring practices but harmonised practices are to be introduced gradually across Scotland.

The charge has three components:

- An attendance charge, to cover the costs of travelling, sample collection and transport expenses. The charge is the same across each RPA's area, but higher charges (£300 per visit as opposed to a standard charge of £32 for 1991/92) are levied for sampling requiring a sea-going vessel.

- A compliance monitoring charge, to cover the costs of analysing and reporting the results of effluent samples. The charge for each band depends on the range of determinands analysed and the frequency of sampling.

- An environmental monitoring charge, to cover the costs of analysing and reporting the results of monitoring the receiving water. Where several effluents containing the same substance are discharged to the same receiving water, the costs of monitoring the substance and evaluating its environmental effects are apportioned among the dischargers in direct proportion either to their compliance monitoring charge or pollutant load.

In addition there is a charge paid by dischargers operating outside their consent conditions requiring RPAs to take additional samples for enforcement purposes.

Objectives of a charging scheme

8.45 We consider that an incentive charging scheme, introduced in addition to the existing system of discharge consents, could be designed to serve several important objectives:

a. It could improve cost-effectiveness. Dischargers with low costs of reducing pollution are likely to reduce their discharges more than firms with higher abatement costs. Reductions in pollution should therefore be achieved in the most cost effective way.

b. It could encourage new technology. A charging scheme could act as an incentive to firms to adopt or develop new technology. Charging might also encourage dischargers to seek out further economically worthwhile improvements through better operating procedures.

c. It could act as a continuing incentive to dischargers to reduce their discharges below present regulatory limits. Regulatory limits are an informed judgment based on imperfect knowledge of environmental impacts and economic implications and are reviewed only intermittently. Charging would encourage dischargers to reduce pollution whenever cost-effective opportunities arose. It would thus be an important component in a policy, such as we set out in chapter 9, whose objective is to reduce pollution and to move towards a situation in which less harm is imposed on the environment.

d. It would reinforce the ‘polluter pays’ principle. Regulatory standards impose costs on dischargers by, for example, requiring them to install pre-treatment facilities. However, firms are not at present charged for the costs that their permitted discharges may impose on others. In some cases these will be tangible and quantifiable; downstream abstractors, for example, may have to spend money treating the abstracted water, or anglers may find their catches reduced. In other cases the effects may not be financial but may be reflected in reduced amenity or the absence of certain species of animals or plants. Some of these costs,
particularly those of programmes to improve water quality, are borne by the public through
general taxation. A charging scheme would be a step towards imposing on dischargers the
full costs of their pollution.

e. **It could provide a strong message to reinforce public attitudes towards pollution.** Consent
systems may be held to give dischargers a 'right to pollute' up to their consent limits. A
charging scheme offers the opportunity to counter any such message. Those who cause
pollution are degrading the environment and should expect to pay for their actions. A
charging scheme, particularly one with increasing unit charges as discharges rise, would
reinforce that message.

f. **It could reinforce regulation.** A charging scheme, as in Germany, which levied a higher charge
on discharges if samples were found to be above consent levels (see paragraph 8.29) could
act as a powerful reinforcement of consents. It could be more consistent and reliable than
prosecution, at less cost to the authorities, while still leaving them free to pursue prosecution
for significant or persistent breaches (see paragraph 8.48).

g. **It could act as a revenue source.** The revenue raised could be used by the regulatory
authorities to fund environmental improvements. It might also be used to fund pollution
reduction investments by industry and so reinforce the impact of the scheme by reducing the
cost of pollution abatement to dischargers. This use of the revenue might also ease
implementation of a scheme.

8.46 We consider that these are valuable objectives which cannot be achieved by the existing
system of consents alone. Incentive charges would thus bring benefits to the aquatic environment
in an economically efficient way. They need not be complex, unnecessarily expensive to administer or an unreasonable burden on industry. We therefore recommend that a charging
scheme for point discharges to water should be adopted in the UK. We describe below the main
attributes which we consider would be desirable in such a scheme.

The scope of the charging scheme

8.47 We consider that an incentive charging scheme should cover all point source discharges
which are subject to consent and that the charge should be related to the polluting potential of the
effluent. The scheme should replace the various cost-recovery schemes operating in Great Britain
and should combine the best features of the continental and the NRA charging schemes. In
particular, the charge should be based on the volume and content of the effluent as specified in the
discharge consent. For simplicity, the charge should be calculated using 'units of pollution' and a
unit of pollution should be set for each of the major measures of pollution such as BOD,
suspended solids, nutrients, toxic metals and so forth. As in the German scheme, the pollution
units should vary with the polluting impact of the substance. So, for example, the unit of pollution
for mercury might be 30g and the unit for BOD might be 25kg. The same charge should be levied
for each unit of pollution. Box 8.10 indicates how the charge might be calculated. The charging
scheme constructed in the Tees study varied with the location of discharges on the Tees, in order
to achieve water quality standards. As we propose that the consent system should be retained to
secure quality standards, we do not consider it necessary to complicate the charging scheme at
this stage by including a locational factor. The system of consents should be operated to take
account of the sensitivity of the receiving water and the likely environmental impact of the
discharges.

8.48 The regulatory authorities already monitor discharges in order to check compliance with
consents. We do not consider that additional monitoring would be required for the purposes of
the charging scheme. When monitoring samples exceed consent levels higher charges should be
levied. As in the German scheme (see paragraph 8.29) the increased charge should be automatic,
triggered simply by sample results, although the details of the system need not be the same as in
Germany. As explained in appendix 6, sample results can be subject to considerable statistical
variability. No explicit allowance need be made for this in determining whether a higher charge is
payable since there would be no necessary implication that a criminal offence had been
committed. Higher charges for samples exceeding consent levels would assist in deterring
infringements of consents which would not currently be considered significant enough to warrant recourse to the courts. They would be an appropriate response, involving no necessary admission of liability, for discharges which, because of statistical and analytical uncertainty, currently fall in the grey area between clearly complying with a consent and clearly infringing it. When the regulatory authorities considered enforcement action was required for breach of a consent, tripartite samples would continue to be needed as now. Reductions in total charges could be offered to firms to encourage them to reduce discharges significantly below their consent levels—for example, by allowing firms to anticipate by 3 years the reduction in charges that would result from investment to reduce pollution, as described in paragraph 8.28.

8.49 In addition to consented discharges, other areas for charging merit consideration. The scope of the charging scheme for point sources might be widened to include these areas or separate schemes might be devised. The areas include:

—— **Storm overflows.** These are not covered by any of the continental schemes. However storm overflows cause a significant level of pollution (see paragraph 7.48) and an annual charge could be levied, related to the design of the storm overflow system, to encourage improvements.

—— **Surface water run-off.** As in Germany31, a formula-based charge could be levied for polluted surface water run-off, for example from roads or large paved areas. Ideally the formula should encourage steps to minimise such run-off or to provide pre-treatment.

—— **Accidental discharges.** A charge could be levied, at a higher than normal rate, on unconsented discharges, including spills, where the discharge could be traced, based on volume and content. This would be in addition to powers which the NRA already has to recover the costs incurred as a result of incidents and in addition to any criminal prosecution or civil action.
Activities that risk pollution. The Government should consider whether charges could be levied on activities such as waste disposal to landfill which risk contamination of surface or groundwater. The charge should be designed so that it encourages steps to reduce risks.

8.50 We have concentrated in this chapter on a charging scheme for consented discharges of pollutants to freshwater and have suggested that the scheme might be extended to other discharges. We have seen earlier in the report, however, that some of the most serious problems of freshwater quality in the UK are the result of pollution originating from highly diffuse sources. The pollution from each individual source is often innocuous; examples include use of phosphate-based detergents by a household, air-borne emissions from a single motor vehicle, use of herbicides in a single garden, silage effluent from a farm (chapters 6 and 7). But the collective (and sometimes cumulative) effects of the pollution are harmful. Pollution of this sort has only recently become a focus of public concern and we consider that it provides an important area in which to explore the further use of economic instruments to reduce pollution. We have not been able to consider the details of schemes to impose charges on products and services whose use contributes to the pollution of freshwater. But several systems have recently been proposed for introducing 'green taxes' on particular products. One possibility might be to introduce a specific 'water charge' which could be imposed on polluting products (such as commercial herbicides or car wash fluids), services (such as dry-cleaning), or 'inputs' (such as silage additives). Even if the charge were set at a very low level, such a system might serve to increase public awareness of the sources and costs of water pollution. Schemes of this sort would of course raise difficult problems of fairness across different users (and producers) and could be implemented only on the basis of wide agreement about the polluting effects in question. But we consider that they are likely to become of increasing interest as efforts to improve water quality come to focus on diffuse pollution sources. We recommend that the Government encourage the EC Commission to explore the possibilities for innovative charging schemes as a means of reducing water pollution from diffuse sources.

The level of the charge

8.51 Ideally, the level of charge should be set on the basis of a valuation of the damage to the environment caused by discharges (see paragraph 8.6). This would include, for example, an amount for loss of amenity. However, we do not think that obtaining such a valuation is a realistic prospect. An alternative approach, adopted in the Tees study (see box 8.2), would be to calculate charges so that, under certain assumptions, they would lead firms to reduce their discharges to levels which would secure achievement of water quality standards. For the reasons explained in paragraph 8.22 we do not consider this approach practicable.

8.52 The experience of the continental schemes, however, provides some general guidelines on the level of the charge. The French charge is claimed to be too low to have any discernible incentive impact (see paragraph 8.34). However, the Dutch and German charges, while considered to be less than the marginal cost to a typical discharger of installing pollution abatement equipment, do appear to be set at levels which influence dischargers' behaviour while not entailing excessive costs. We therefore recommend that the level of charge should be comparable to those in the Netherlands and Germany. Box 8.11 gives a comparison of how much a discharger might be charged under the current NRA scheme (which is not, of course, designed to have an incentive effect) and the German scheme.

Timescale for implementation

8.53 Such a charge level might impose significant extra costs on industry. The German scheme was implemented gradually. Firms were given 5 years' notice of the scheme and the charge was introduced at a low level rising annually on a pre-determined scale. This gave dischargers time to adjust to the new system. Both the Tees study and the study by Stirling University on the Forth Estuary indicated that total costs to firms were sensitive to the time scale for the investment
It should be noted that the German scheme and the NRA scheme differ in both design and purpose. The total charge for the same discharge may vary greatly between countries for some compositions of discharges though for others it could be broadly similar.

A. A manufacturer with a consent to discharge into a river that specified:

**Flow:** 20,000 m³/day
**COD:** 2,000 g/m³
**Copper:** 27 g/m³

1. **Charges in Germany**
   - discharge = 40,000 kg/day
   - pollution unit for COD = 50 kg

800 units of noxiousness

2. **Charges under NRA scheme**
   - Content falls into higher band for copper (B), factor = 5.0
   - Volume falls into 5th band with factor = 5.0
   - Receiving water falls into surface band, factor = 1.0

Charge for 1991 is DM 50/unit

For COD

\[
\text{charge} = 800 \times 50 = 40,000 \\
\text{pollution unit for COD} = 50 \times 800 = 40,000
\]

So total charge is

\[
(800 + 540) \times \text{DM } 50 = \text{DM } 67,000
\]

(approx £23,000)

(approx £1 = DM2.9)

B. A manufacturer with a consent to discharge into a river that specified:

**Flow:** 5,000 m³/day
**Nickel:** 50 g/m³

1. **Charges in Germany**
   - discharge = 250 kg/day
   - pollution unit for nickel = 500 g

500 units of noxiousness

2. **Charges under NRA scheme**
   - Content falls into band B, factor = 5.0
   - Volume falls into 4th band with factor = 3.0
   - Receiving water falls into surface band, factor = 1.0

Charge for 1991 is DM 50/unit

For Nickel

\[
\text{charge} = 500 \times 50 = 25,000 \\
\text{pollution unit for nickel} = 500 \times 500 = 250,000
\]

So total charge is

\[
500 \times 50 = 25,000
\]

(approx £8,600)

(approx £1 = DM 2.9)

*Reductions of up to 75% are available on the charges (see paragraph 8.28).
programme (see boxes 8.2 and 8.3). Gradual implementation would enable firms to take advantage of planned programmes of investment, although it would both reduce the available revenue in the initial years and defer the environmental benefit of reduced discharges. We recommend that the charge should be set initially at such a level that the total income generated would be roughly similar to that generated under the NRA’s cost recovery scheme. The charge should then be increased in annual steps according to a published, pre-determined programme to reach the desired level over a period of about 5 years.

Responsibility for the collection of charges and payment of grants

8.54 The NRA in England and Wales, RPAs in Scotland and DOE(NI) in Northern Ireland are responsible for water quality and for setting, monitoring and enforcing consents. The NRA and RPAs are also responsible for administering the new cost-recovery charging schemes. It would be appropriate for these bodies to be responsible for the collection and calculation of charges and for paying out any grants associated with the incentive charging scheme and we so recommend.

Use of the revenue

8.55 We recommend that the revenue should be available to the regulatory authorities not only to cover the costs of regulation as with the present cost-recovery schemes but also to fund pollution prevention measures and programmes and research to improve water quality. The revenue might be used, for example, to clean up water which is polluted by heavy metal accumulation in river sediments. Unless it is inconsistent with European Community legislation on state aids we also recommend that the Government should consider introducing a scheme, similar to those operating in Germany and the other countries discussed above, to provide grants to industry for investment in pollution abatement, funded by the income from the charges. Such a grant regime could be administered by the NRA, RPAs and DOE(NI) and the grants could be available to all dischargers liable for the charges. Loans for pollution abatement investment might also be offered under the scheme. Clear guidance would need to be provided as to the types of investment that would qualify for grant aid or loans and the criteria that should be satisfied. For example, grants could be made available to install pre-treatment facilities in industrial plant or to improve sewerage systems to reduce the load on storm-overflows. In Germany in 1986, 80% of the revenue raised by the charges was used to support investment in pollution abatement technology by local authorities and industry. Such grants would reinforce the incentive effect of the charges and help industry to adapt to the new financial context.

8.56 Such grants are open to criticism on the grounds that, if the charges are set at the optimal level, in the sense that the charge levied on each firm results in the most economically efficient level of investment in pollution abatement, then the use of revenue for grants would lead to an over-investment in pollution abatement and thus an inefficient use of resources. In practice, as pointed out in paragraph 8.51, we consider that it is not realistic to think in terms of calculating the optimal level of charges. Other countries’ experience suggests and we recommend in paragraph 8.53 that, certainly initially, the charge will be set lower rather than higher, so that too much investment resulting from such grants is unlikely. Another concern with a grants system is that it might encourage investment in capital spending schemes when resources to improve the water environment could be better spent in other ways. To mitigate this possibility, we suggest that any grant scheme should not be restricted to capital projects but should also cover other activities, such as training and research, designed to reduce pollution.

8.57 There may also be equity problems when introducing a grants scheme. A discharger with a poor record of investment in pollution abatement technology would benefit from grants for such investments while a comparable firm that had previously introduced the best technology and practices would have paid the full cost. This discrepancy would, of course, be reduced by the lower charges the latter discharger would be paying from the outset and would, in any case, be of declining relevance as time passed.

8.58 It is not necessary for the revenue from charges to be used to fund expenditure on pollution prevention and treatment nor, if it is used in that way, for it to set a limit on the amount of
Chapter 8

prevention and treatment work carried out. However, we consider that using the revenue from charges to supplement funds for water quality improvement is desirable and would be consistent with the 'polluter pays' principle.

Sewage treatment works

8.59 We recommend that sewage disposal should be covered by the charging and any grants schemes in the same way as other point discharges. However, sewerage undertakers have a monopoly in the supply of sewerage facilities. Charging sewage treatment works may therefore lead to charges merely being passed on to consumers rather than acting as an incentive on the sewerage undertakers to invest in pollution abatement technology. Because of this, the role of the regulators of the undertakers—OFWAT, DOE, Scottish Office and DOE(NI)—would be crucial, in order to ensure the undertakers had a financial incentive to improve their discharges. OFWAT and DOE would also need to consider what pricing and other implications there might be for the privatised water companies in England and Wales as a result of any grants scheme for investment in pollution abatement for which they would be eligible.

Cross-media distortions

8.60 Requiring polluters to pay for discharges into water without making a similar requirement for discharges to other environmental media might introduce a distortion by encouraging firms to discharge to media other than water. Other media will continue to receive the protection of existing regulatory controls and there may often be little scope for such transfers. The composition of sewage effluent, for example, means that it must continue to be discharged to water, though there may be some scope to reduce its polluting impact on water at the expense of an increase in the volume of sewage sludge requiring disposal. The experience of the continental countries has not highlighted cross-media transfers of pollution as a drawback of their schemes. We do not therefore consider that the possibility of such distortions occurring should slow the implementation of a charging scheme for water pollution. However, to move towards consistent treatment we recommend that the Government should examine the scope for the introduction of market mechanisms for the disposal of pollutants to air and land. This would help to reduce any risk of discouraging dischargers from choosing the best practicable environmental option for disposal of their wastes.

International aspects

8.61 Theoretically, it is possible that the introduction of a charging scheme in the UK could adversely affect the competitiveness of UK industry. Studies of the charging schemes operating in France, Germany and the Netherlands have not, however, identified this as an issue in those countries. It does not seem likely that a broadly similar level of charge would have a significant detrimental effect on UK industry.

8.62 We understand that discussions on water pollution charging systems have taken place within the European Community since 1976 and that, more recently, the wider application of market mechanisms to pollution control, including water pollution control, have been discussed. Such discussions are welcome but we do not consider that the implementation in the UK of the scheme we propose need await EC action.
CHAPTER 9
INHERITANCE FROM THE PAST AND LEGACY FOR THE FUTURE

Introduction

9.1 Chapter 1 identified three aspects of water quality management which we consider to be an essential foundation on which to base policy: sustainable use, conflict management and impact on other parts of the environment. Later chapters have described some important problems of freshwater pollution and contain recommendations for dealing with them. This chapter addresses some general issues which have emerged in the course of the study:

— Action to improve, or even to maintain, water quality requires careful planning; it must also be integrated with other plans and actions which affect the environment, such as development control.

— The achievement of objectives for water quality requires effective instruments of pollution control.

— Policies for water quality are, increasingly, being developed in the context of the European Community.

— Programmes for improving water quality require planning over a long timescale; so short term objectives need to be set within the context of longer term aims.

Planning

Water resource planning

9.2 Freshwater quality is affected by activities which alter the flow of rivers—such as abstraction, impoundment, drainage and flood prevention—as well as by pollution. The sustainable use of freshwater and the management of conflicting uses must therefore encompass the control both of flows and of pollution. This link between water quantity and quality is an important element in integrated river basin management, which has been central to water policy in England and Wales for many years. The NRA's Corporate Plan recognises this and it has been emphasised in evidence we have received. In chapter 1 we point out that every significant river in the UK, and many minor ones, receives discharges of effluents. The lower the flow rate of a receiving river, the greater the impact of a given quantity of pollutant on its quality. Abstraction and discharge controls must therefore be exercised in an integrated fashion to ensure that the desired quality is maintained. In 1991 the Government published proposals to establish an Environment Agency in England and Wales. One of the four options in the consultation paper involved placing responsibility for water resources, including abstraction controls, and responsibility for water quality in different regulatory authorities. Such an arrangement would severely inhibit the scope for integrated planning and operation of these responsibilities. It would also make much harder the development of a system of catchment management plans as described in paragraphs 9.9 et seq. We therefore consider that that option should not be pursued and, as explained in our response to the consultation paper, we recommend that the Government ensure that future arrangements for the control of freshwater pollution in England and Wales will enable the integration of water quality and quantity regulation to be maintained and enhanced. The position in Scotland is considered in paragraphs 9.6 and 9.7.

9.3 The recent succession of dry years has focused attention on the effects of inadequate flows on water quality. A few rivers have dried up completely. The NRA has instituted a programme to alleviate the worst affected cases (see box 9.1) and is identifying minimum acceptable flows in its catchment planning process (see paragraph 9.9). We recommend that it should develop the concept further. Aims for minimum flows provide a framework for setting discharge consents and
abstraction licences and for supplementing flows by water released from reservoirs or pumped from boreholes. The Water Resources Act enables statutory minimum acceptable flows to be set for inland waters. Whilst recognising the practical difficulties involved in determining and maintaining minimum acceptable levels, we recommend that the NRA should consider whether the use of this power might help to strengthen control over activities affecting quantity and quality.

**BOX 9.1 LOW FLOWS IN RIVERS**

Following a review of rivers suffering from low flows, the NRA drew up a priority list of 20 sites (see figure 9.1) and in 1991 set out a programme of action for 16 rivers requiring urgent action. These are:

<table>
<thead>
<tr>
<th>Anglian</th>
<th>Thames</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hiz near Hitchin, Herts</td>
<td>Misbourne, near Amersham, Bucks</td>
</tr>
<tr>
<td>Slea at Sleaford, Lincs</td>
<td>Ver, near St Albans, Herts</td>
</tr>
<tr>
<td>Waveney at Redgrave and Lopham Fens, Cambs</td>
<td>Pang, Berkshire</td>
</tr>
<tr>
<td></td>
<td>Wey, near Alton, Hants</td>
</tr>
<tr>
<td></td>
<td>Letcombe Brook, near Wantage, Oxon</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Severn-Trent</th>
<th>Wessex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worfe, Shropshire</td>
<td>Piddle, near Briantspuddle, Dorset</td>
</tr>
<tr>
<td>Battlefield Brook, near Bromsgrove, Hereford &amp; Worcs</td>
<td>Allen, near Stanbridge, Dorset</td>
</tr>
<tr>
<td></td>
<td>Wey, near Upwey, Dorset</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Southern</th>
<th>North West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darent, Kent</td>
<td>Lowther, near Haweswater, Cumbria</td>
</tr>
<tr>
<td>Wallop Brook, near Stockbridge, Hants</td>
<td></td>
</tr>
</tbody>
</table>

One of the most serious cases is the Darent in Kent (see plate 10). At the height of the drought in 1990, Thames Water pumped groundwater into the river at several points and the NRA traced water leaking from the river. Consultants have been appointed to study underground water reserves in the Darent valley. Possible solutions include relocating public water supply abstractions so that they have less impact on river flows, partial revocation of abstraction licences and augmenting river flows with water pumped in from boreholes. Short term solutions could take some 5 years to implement at a cost of up to £10 million. Long term solutions could take up to 10 years; their costs have not yet been estimated.

9.4 The NRA has published recently a discussion document on the balance between water resources and demands in England and Wales. It is part of the process of preparing a water resources development strategy, which the NRA expects to have in place during 1993. The document presents on a regional basis information about likely demands over the next 30 years and options for meeting demands. The wetter north and west are likely to continue to be in surplus and the NRA considers that inter-regional transfer schemes should be investigated as a potential way of meeting any long term shortfalls in the south and east. Equally important are measures which could reduce the need to abstract water, for example by reducing leakage from supply mains and by encouraging economy in the use of water. Economic instruments could offer useful incentives in these areas, for example through the development of the charging scheme for abstractions. There may, however, remain a need to take action in some areas to bring abstractions in line with the available resources. The NRA is considering the need to amend or revoke abstraction licences in some of the cases listed in box 9.1. Some licence holders may be statutorily entitled to compensation for loss of or restrictions on their licences. The Government will need to ensure that adequate funds are made available to the NRA for any such cases.

9.5 Nature conservation can be severely affected by abstraction. Specialised animals and plants of wetlands, for example, can be very sensitive to changes in water levels, as described in
Other impacts include the effect on migratory fish of insufficient flows of water of the right quality at the right time of year to enable them to complete their migrations. We support the view expressed to us in evidence by the former NCC that, in considering applications for abstraction, the NRA should give weight to the desirability of preserving important natural sites as well as of furnishing public supplies.

Although problems of priority for the use of water resources in England and Wales continue, the comprehensive system of licensing and registration of water abstractions does enable control to be exercised. In Scotland, rights to water use, with some exceptions, are governed by common law. The Scottish Office told us\textsuperscript{10} that, because adequate supplies of high quality water were available in Scotland, it considered that a comprehensive system of abstraction control was not justified. The Government has, however, taken powers\textsuperscript{11} to establish an annual licensing system covering abstraction for irrigation for agriculture. The Scottish Office acknowledged that the abstraction of large amounts of water for freshwater fish farms could significantly reduce the dilution available for effluents but considered that serious depletion occurred in very few cases and was not aware of any demands for major new abstractions.

The Scottish River Purification Boards Association considered\textsuperscript{12} that full powers of control are needed and pointed to some difficulties which have arisen. These do not yet appear to be widespread, except perhaps in relation to fish farms. Nevertheless we believe that there is merit in the views expressed by the Association and recommend that the Government should look again at the case for licensing all water abstraction in Scotland. As well as tackling existing difficulties, this would provide a better basis for regulating any new demands for water. We recommend that, as in England and Wales, such controls should be exercised by the authorities responsible for regulating water quality, currently the river purification authorities but, under recent Government proposals\textsuperscript{13}, to be taken over by a new Scottish Environment Protection Agency. In Northern
Chapter 9

BOX 9.2 FENS AFFECTED BY WATER ABSTRACTION

Redgrave and Lopham Fens in Suffolk, and Chippenham Fen in Cambridgeshire, are examples of sites at which abstraction of water has resulted, or might result, in the loss of rare animals and plants.

Redgrave and Lopham Fens are SSSIs and Redgrave is a designated wetland site of international importance. More than 25 species of plant, many of which are rare and which require wet fen conditions, have disappeared from Redgrave Fen and others are at risk of disappearing. The great raft spider, which has been found at only one other site in England, has been lost from several areas of these fens because many pools have completely dried out. There has also been a marked change in habitat: plant species such as saw sedge and black bog-rush, indicative of base-rich peat fed by springs, have been replaced by species such as birch and sallow which can tolerate a broader range of conditions. These changes reflect fen desiccation.

Suffolk Water has abstracted about 900,000 m³ of water annually for 35 years from the chalk aquifer below the Redgrave and Lopham Fens. Together with Suffolk Wildlife Trust, and the NRA, it is now considering a proposal to move the abstraction point to one which will not diminish the water table in the fens. It is also pumping water from the present borehole to a small number of pits at Little Fen and Middle Fen to support part of the great raft spider population.

Chippenham Fen is important for its ecological diversity: it contains not only areas of characteristic sedge fen but also fen meadow, chalk grassland, carr and taller woodland. More than 300 species of flowering plants are recorded there, including Cambridge milk parsley which occurs at only three sites in Britain. Many other plants now rare or local to East Anglia occur. The Fen is also famous for its rich fauna, especially invertebrates such as the silver barred moth.

Extensive abstraction of groundwater has resulted in a reduction of spring flows in the Fen and there is concern that this might reduce its ecological diversity. A feasibility study showed that it is possible to compensate reductions in spring flows by pumping water from an aquifer to maintain target flows in streams. Anglian Water is constructing a river support scheme which consists of six boreholes supplying water to thirteen springheads. The springs in the Fen will also be supported with groundwater. As a result, river and environmental needs will be met and it will be possible to increase abstraction from some boreholes.

Ireland there is no system of abstraction licensing but a review is under way. We recommend that the review should take full account of the importance of managing water quality and quantity in an integrated fashion.

9.8 Land drainage, flood prevention and other activities calculated to change water flows also affect water quality as well as wider environmental quality. Officials from the Netherlands government illustrated for us the steps that are being taken in their country to bring a wider consideration of environmental quality into the hydraulic design of water courses, flood prevention, land drainage and navigation. These issues are of course particularly important in the Netherlands but similar developments in thinking are taking place in this country.

Catchment management plans

9.9 It is impossible to separate the management of waters from that of land: the whole drainage basin — or catchment — must be considered as a unit for water management. The NRA has decided that the best way of bringing together these considerations is through a process of catchment management planning aimed at balancing the demands of all water users and involving consultation with interested parties. The process will include an appraisal of a catchment to identify present and potential uses of water and associated land, consider interactions and possible conflicts, and develop an action plan which allocates responsibilities for achieving improvements. This will involve an analysis of financial and other implications of the desired environmental quality goals. Water quality objectives, discussed in chapter 4, would be
BOX 9.3  RIVER TORRIDGE CATCHMENT MANAGEMENT PLAN

The South West Region of the NRA was the first to produce a catchment management plan. It covers the catchment of the river Torridge in Devon. Linked with it will be plans for the river Taw and for their common estuary. The plans are being produced in two stages. The first identifies:

- the uses of the catchment;
- the environmental requirements for each use;
- the present state of the catchment compared with these targets; and
- gaps in knowledge, known problems and conflicts, and suggested solutions where these are easily identifiable.

On the basis of the stage 1 plan for the Torridge, a document was issued for public consultation. Solutions to the problems identified in it will be presented in a stage 2 plan. It is proposed that the stage 2 document should cover both rivers and their estuary.

Stage 1

After an overview of the geology, hydrography, ecology and land use of the catchment, the plan describes the various uses to which the watercourse itself is put: for sports, conservation, fisheries, potable and other abstraction and effluent disposal. It indicates the water quality of each stretch of water in the catchment and the targets for quality, resources, fisheries and flood defence which would be required in order to satisfy the various uses. By comparing the actual quality with the targets, the main problems are identified. Stretches of water which fail to meet the targets for BOD, ammonia etc are indicated on a map, as are those where fisheries show cause for concern or where there are known flooding problems.

Stage 2

This will represent the plan of action for the catchment, identifying the nature and cause of each problem, presenting a solution formulated after consultation with other parties and identifying the body responsible for action and a timetable for the work to be carried out.

an important part of these plans as would information about minimum acceptable river flows and about transfers of water into and out of the catchment. Pilot plans in priority catchments are being drawn up and, depending on their outcome, procedures will be derived for national application. One such pilot plan is described in box 9.317,18.

9.10 We commend the development of catchment management plans. In some parts of the country plans will need to encompass the links between surface waters and groundwaters. In chapter 5 we recommend the development of aquifer protection policies on a more comprehensive basis than hitherto; these could be brought together with the associated catchment plans.

9.11 One aspect of catchment management is the identification and removal of threats to abstractions for public supply. Northumbrian Water Ltd has initiated an exercise to identify pollution risks to its abstraction sources (see box 9.4)19 which provides useful pointers for methodology and relative risks. Some of the study's conclusions will be capable of implementation by Northumbrian Water. Others will require co-operation with organisations such as the NRA, which alone has the powers to control many of the pollution sources identified and the ability to take account of the full range of uses of water resources in the region.

Land use planning

9.12 Land use affects water quality even if distant from the watercourse. Catchment plans must therefore take full account of likely land use changes. Equally, decisions which might lead to
changes in land use need to take account of their likely effect on water quality. The case studies of the Tame and the Bedford Ouse, prepared for us by WRc (appendix 5), provide contrasting illustrations of the consequences of land use changes. In the early 19th century the Tame provided drinking water for the city of Birmingham, whose population was then about one-third of a million people (now about one million). Industrial and urban development led to pollution of the Tame and its abandonment as a source of potable water, to be replaced largely by water brought from sources in Wales. The Tame remains today heavily polluted from sources such as contaminated land, urban run-off and sewer overflows. The catchment of the Bedford Ouse has also experienced major urban development, in particular with the construction since the 1960s of a large new town, Milton Keynes, around the headwaters and with continuing population growth in the region. River quality is affected to an extent by treated effluents and by intensive agriculture in the catchment. Detailed planning and careful control of potential pollution sources have, however, enabled the river to continue as an important abstraction source for public supply. Chapters 6 and 7 refer to other changes in land use which can have important adverse effects on water quality, including road construction, afforestation and deforestation and the establishment of fish farms.

<table>
<thead>
<tr>
<th>BOX 9.4 IDENTIFICATION OF RISKS TO WATER SUPPLIES</th>
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<tbody>
<tr>
<td>Binnie &amp; Partners were engaged by Northumbrian Water Ltd (NW) to carry out studies for ten water treatment works operated by the water company. The studies were intended to:</td>
</tr>
<tr>
<td>- identify the pollution hazards to the raw water supply;</td>
</tr>
<tr>
<td>- review the facilities for detecting contamination before or at the works;</td>
</tr>
<tr>
<td>- review the ability of the existing treatment processes to deal with contaminated water; and</td>
</tr>
<tr>
<td>- make recommendations for improvements in the light of the pollution risks.</td>
</tr>
<tr>
<td>The potential hazards in the catchment were identified by:</td>
</tr>
<tr>
<td>- study of Ordnance Survey maps;</td>
</tr>
<tr>
<td>- field reconnaissance, by car and on foot;</td>
</tr>
<tr>
<td>- enquiries to local farmers, occupiers of industrial premises etc.</td>
</tr>
<tr>
<td>- discussions with officers of various bodies having a role in health, planning and pollution control;</td>
</tr>
<tr>
<td>- a search of local directories;</td>
</tr>
<tr>
<td>- acquisition of data, including:</td>
</tr>
<tr>
<td>NRA</td>
</tr>
<tr>
<td>MAFF</td>
</tr>
<tr>
<td>OPCS</td>
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<tr>
<td>DTp</td>
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<tr>
<td>County</td>
</tr>
<tr>
<td>NW</td>
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</tbody>
</table>

One of the outputs of the study was a matrix of potential hazards arising from a range of activities including farming, industrial processes, construction, roads and petrol filling stations, residential areas, sewer overflows and powerboating.

The study included the construction of a table of critical pollution loads in the river Tees for each abstraction point on it. This gave the quantities of polluting substances which, if reaching the river at certain stated locations, would cause the relevant guideline concentrations and alarm levels to be exceeded at that abstraction point.
9.13 Many changes in land use are controlled through town and country planning legislation which enables protection of freshwaters to be taken into account in the evaluation of proposed developments. As a consequence of the Planning and Compensation Act 1991 local planning authorities must now take account of environmental considerations in preparing their development plans. This requirement is backed up by policy guidance on planning and the environment and on the environmental appraisal of plans. Authorities are required to consult the NRA and English Nature, amongst others, when drawing up development plans. They are also advised to consult the relevant water company on certain matters relating to water and sewerage services. Coupled with the requirement in the 1991 Act that planning decisions must be made in accordance with the development plan for the area unless material considerations indicate otherwise, these arrangements offer the opportunity for substantial strengthening of the protection afforded to the environment through the land use planning system. We recommend that planning authorities should ensure, through consultation with the water regulatory authorities, that their development plans take full account of the need to protect both the quantity and the quality of water resources. We are pleased to note that the Government has issued advice\textsuperscript{20,21} to planning authorities in England and Wales that ‘those impacts on the environment which may be irreversible or very difficult to undo should be treated with particular care in the preparation of plans.’ The Government’s advice asks planning authorities to pay special attention to the protection of groundwater and to take into account the series of maps the NRA is preparing which will identify areas of concern (see paragraph 5.23). In Scotland, Government advice\textsuperscript{22} draws the attention of planning authorities to the need to safeguard groundwater for future use and to protect existing sources. The Government is examining the need for further guidance in this area as part of a current review of all planning guidance. We recommend that water regulatory authorities for their part should consider what kinds of land use proposal might prejudice freshwater resources and draw these to the attention of planning authorities to take into account in development plans. Catchment management plans offer a suitable vehicle for identifying such proposals; incorporating appropriate policies in development plans would help to increase the influence of catchment plans.

9.14 When planning applications are received the water regulatory authorities are consulted statutorily for certain classes of development with a high water pollution potential\textsuperscript{23,24}. Nature conservation councils are consulted about developments in, adjacent to, or likely to affect sites of special scientific interests\textsuperscript{25,26}. In addition, planning authorities in England and Wales are advised by the Government\textsuperscript{27} to consult the NRA about development likely to increase industrial discharge into a river or estuary and about development in flood plains or areas with a high water table; and to consult water and sewerage undertakers on any planning application likely to have significant implications for the services they provide. In Scotland no such advice has been issued but the Regional Councils are the water and drainage authorities and are either planning authorities in their own right or are consulted as a matter of practice by the District Council planning authorities.

9.15 It is encouraging that, in many areas, close working relationships are being developed between planning authorities, developers, the water regulatory authorities and water and sewerage undertakers. The differences between the boundaries of the various authorities emphasise the importance of close and co-operative working relationships between all the parties. Nevertheless there is scope to improve arrangements further. We recommend, first, that planning authorities should be required to consult the water regulatory authorities and the water and sewerage undertakers on proposals of significant concern to them. Secondly, the existing arrangements should be strengthened to allow interested parties the right to be informed of the basis for a planning authority’s decision. We recommend that a planning authority which takes a decision against the advice of a statutory consultee should be required to provide, on request, a statement of its reasons for not following that advice. This would help to ensure that such advice was properly considered and was seen to be so. This issue goes beyond the field of water pollution and our proposal should be capable of application to all planning decisions.

9.16 Procedures for assessing the likely impact on water quality of proposed land use changes have been strengthened by the introduction of an environmental assessment procedure which stems from the implementation of a European Community directive\textsuperscript{28}. The directive lists, in
Chapter 9

Annex I, types of development which will always require environmental assessment and, in Annex II, types which will be subject to assessment ‘where member states consider that their characteristics so require’. In the UK this is interpreted as requiring assessments where projects ‘are likely to have significant effects on the environment by virtue of factors such as their nature, size or location.’ The Government has offered advice on assessing significance and on indicative criteria and thresholds to assist in decisions on whether Annex II projects that require planning permission would be likely to require environmental assessment. For example, the Government suggests that pig and poultry rearing installations will not generally require an assessment but may do so if designed to house more than 400 sows, 5,000 fattening pigs, 100,000 broilers or 50,000 layers. Depending on local circumstances the Government advises that salmon farms designed to produce less than 100 tonnes of fish a year would not normally require assessment. We recommend that the Government review these criteria and thresholds. As will be clear from our discussion in chapter 7 of the impact that intensive livestock units and fish farms can have on water quality, developments on a scale below these suggested thresholds can cause significant pollution.

9.17 There is no size limit below which a project can be guaranteed to have no significant environmental impact. Consideration of environmental impact in many more proposed developments would greatly assist in ensuring that environmental issues were taken fully into account in decisions on planning applications. It would also help to widen public appreciation of environmental problems and of the practicalities of dealing with them. When a local planning authority considers a planning application, it may request information about the likely effects on the environment. We recommend that the Government encourage authorities to exercise this power unless they consider the environmental impact is likely to be minimal. It should issue guidance on information which would be suitable in different cases, so that the information sought is appropriate to the scale and nature of the project and its potential environmental impact. In the case of developments of a type listed in Annex II to the Directive, but not requiring full environmental assessment, the information requirements might be little short of those specified in the Directive, whilst for other developments they might be very much simpler. Organisations such as the Environment Council, which is already assisting small firms with environmental audits, might be able to devise suitable procedures in this area also, as might environmental departments in universities. We recommend that the Government encourage this with a view to devising straightforward arrangements appropriate to the task.

9.18 Not all changes of land use come within planning control, particularly where agriculture and forestry are concerned. The water legislation contains powers, however, to bring under control activities that may adversely affect water quality. Nitrate Sensitive Areas have been designated on an experimental basis to investigate ways of changing farming practices in order to reduce nitrate levels in water (see paragraph 7.132). The legislation also contains powers to designate Water Protection Zones, powers which existed in the Control of Pollution Act 1974 but which have never been used. In chapter 5 we recommend the use of these powers to protect groundwaters and they are also available for the protection of surface waters. The former Welsh Water Authority developed proposals, now being considered further by the NRA, for a water protection zone for the river Dee. We recommend that the water regulatory authorities draw up lists of vulnerable watercourses which might benefit from such protection, particularly those which are threatened by activities not susceptible to control through the land use planning system, and that the Government consider favourably applications from them for designation of protection zones.

Water pollution controls

9.19 Policies and plans need effective and flexible instruments of pollution control if they are to succeed. The UK system of discharge consents based on water quality objectives and standards is described in box 7.1. One feature of this system is that consents can be set to take account of river flows and the cumulative impact of point discharges, diffuse sources and polluting inputs released from sediments. Tighter consents can thus be set where needed to protect small rivers or where point discharges would exacerbate problems resulting from other inputs. In recent years this system has been supplemented by a recognition that some pollutants are potentially so hazardous,
either to man or the environment, that they need to be the subject of additional, technology-based controls. This has led to the development of the 'Red List' described in appendix 4.

9.20 Although the basis for controlling discharges in the UK has been well-founded its implementation has not always been satisfactory. It appears from the evidence we received that inadequate control over discharges is ascribed to the manner in which the regulations have been implemented by the responsible authorities rather than to the framework of regulation. In particular, there have been criticisms of the levels at which consents have been set and of the lack of firmness with which they have sometimes been enforced. Much criticism has focused on discharges from sewage treatment works (STWs) and the series of relaxations of their consents in England and Wales during the 1980s in the face of deteriorating performance attributed to lack of investment (see paragraph 7.28). In Scotland, no relaxations of STW consents have occurred and the Scottish Office considered that such consents have in general been more environmentally protective than those in England and Wales. Criticisms were also made of the perceived reluctance of the former water authorities in England and Wales to take an appropriately firm attitude towards breaches of consents by dischargers. The authorities themselves attributed this in part to their experiences in failing to secure, in court, penalties which they considered appropriate to the offences. Others ascribed it to the authorities' vulnerability to criticism for their own discharges from STWs.

9.21 Whatever the reasons, a marked contrast is now visible in the high planned rates of investment designed to improve discharges from STWs, their improved compliance with consents and the active enforcement policy adopted by the NRA. We warmly welcome these recent developments. Deterioration in the quality of water is not, in our view, acceptable other than as a short term expedient in exceptional circumstances. It represents an unsustainable use of the environment which, if not corrected, ultimately imposes costs which future generations have to bear. We believe that the public views an improving environment as an important priority and there appears to be a willingness to bear the associated costs.

9.22 The active enforcement policy adopted by the NRA has been widely welcomed. Enforcement must be the subject of a clear, consistent and publicly defensible policy. There may be valid reasons for being flexible about prosecuting offenders but these need to be publicly explained and backed by appropriate and visible alternatives which can be seen to achieve the desired ends. In its conclusions on the consultation document on consent compliance, known as the Kinnersley Report, the NRA stated that it was concerned to strike the right balance between warning a discharger about a deteriorating quality of discharge, taking action on a rare and marginal breach of a consent and dealing with blatant and persistent failures to comply. It set out a hierarchical procedure ranging from warning letters, through letters of caution to prosecution. We endorse such an approach. We understand that the Scottish RPBs have recently adopted a common enforcement policy which is now stated in their corporate plans and is very much on the lines of the NRA's. Not every breach of a consent will merit prosecution. In some cases, for example, the evidence may not be strong enough for the authority to be confident of conviction, or there may be mitigating circumstances. The regulatory authorities should ensure, however, that serious, repeated or reckless breaches of consents will lead to prosecution. We point out in chapter 8 that a suitably designed charging scheme for effluents could help to reinforce compliance with consents.

9.23 Improved compliance with consents may often be achieved at relatively little cost by changes in operating practices and attention to procedures. The Kinnersley Report proposed that dischargers should identify 'a manager of an appropriate level to take a direct interest in the good operation of the discharges.' It sought in general to encourage dischargers to take 'a positive management interest in their performance in waste disposal' and proposed that the NRA would maintain a dialogue with dischargers. We consider that these are sound objectives. For them to be effective, however, the person made responsible for discharges must have commensurate authority. The report's recommendations generated concerns about individuals in companies being the target for legal action. We consider that to be a separate matter which should not prevent companies from ensuring that responsibility for their discharges lies with a manager at an
appropriately senior level with commensurate authority who is in a position to engage in constructive dialogue with the regulators. We recommend that dischargers put such arrangements in place.

9.24 A firm approach by the regulatory authorities towards breaches of consents needs to be matched by a willingness on the part of the courts to impose fines which reflect the gravity of the offences. The maximum fine that can be imposed in Magistrates' courts in England and Wales, and in Sheriffs' courts in Scotland, was raised in 1990 from £2,000 to £20,000. In Crown courts there is no upper limit on the fine that can be imposed. Between 1989/90 and 1990/91 the average fine imposed in England and Wales is reported to have increased to £1,047 from £886 (excluding from the latter an exceptionally large fine of £1 million imposed for an oil pollution incident in the Mersey estuary). The number of cases is reported to have risen from 309 to 49035. The NRA is also able to claim costs and damages in appropriate cases. We encourage the NRA to seek severe fines and the award of costs and damages in cases of serious pollution and to take the most serious cases to the Crown Courts.

9.25 We were informed that, in Northern Ireland, the regulatory authorities have an active enforcement record. In Scotland, all criminal prosecutions are undertaken by procurators fiscal; those concerning water pollution are generally taken at the instigation of river purification authorities. During our visit to Scotland for this study the Scottish River Purification Boards Association suggested to us that procurators fiscal did not always accord a sufficiently high priority to alleged water pollution offences. We did not investigate whether this claim was justified but, since then, the Association reports that there have been useful discussions with the legal authorities and with the Scottish Office about the need to bring prosecutions in cases of serious pollution and to impose appropriately severe fines. The Clyde RPB told us that improved staffing levels have enabled it to refer to procurators fiscal an increasing number of cases for prosecution. The Board commented that its position would be helped if it had the power to recover costs associated with the prosecution as does the NRA in England and Wales. We recommend that the Government emphasise to the legal authorities in Scotland the importance of enforcing water pollution legislation so that river purification authorities can have confidence that cases will be taken to court where relevant evidence is available. We further recommend that the Government seek means of enabling river purification authorities to recover their costs.

9.26 It is much more difficult to establish regulatory control over diffuse pollution than over point discharges. Yet diffuse sources cause serious water pollution. Indeed, as pollution from point discharges is progressively reduced, further improvements in quality increasingly depend on reducing diffuse pollution. In some cases it may be possible to convert diffuse pollution into a point source which can then be more easily controlled, for example, by installing drains to collect the run-off from land and diverting the drainage water to sewer. In most cases, however, control action must be addressed to the activities which lie behind the diffuse inputs. Examples would be the imposition of limits on acid emissions from power stations or on fertiliser and pesticide applications on farms, as discussed in chapters 5, 6 and 7. Either direct regulatory controls, economic incentives or both could be introduced. Beyond this, controls over location of activities can be used to prevent their giving rise to diffuse pollution. Examples here would include the introduction of limits on afforestation to reduce acidification problems, as discussed in chapter 6, and the designation of buffer strips alongside rivers in agricultural areas to reduce problems of nitrate and pesticides entering the water.

Pollution prevention

9.27 Some pollution problems may be so severe and so deep-seated that full amelioration is very difficult to achieve. The Tame in the West Midlands provides one illustration of the problems that can occur, as described in appendix 5. Even when present sources of pollution have been tackled, the river will remain of poor quality. It is polluted by heavy contamination of the local soils and aquifers, mainly as the result of two hundred years of industrial activity. An approach to water quality founded on sustainable use would aim to prevent such situations developing in future. The parallel case of the Bedford Ouse, also described in appendix 5, illustrates the care the authorities took to protect that river against impacts from new urban
development. The numerous abstraction sources on the river provided a powerful motivation for its protection but the principle of sustainable use would require a similarly careful, preventive approach in all cases where contamination were possible, even if no abstraction were planned.

9.28 The catchment management and land use planning activities described earlier in this chapter have, among their main aims, prevention of environmental problems. Other initiatives can also contribute towards this aim. There is evidence, discussed in chapter 7, that advisory programmes have helped to reduce pollution incidents on farms. The Government has recently introduced regulations to improve the standards of slurry and other stores on farms. It also has the power to introduce regulations covering the construction of stores on non-agricultural premises and has indicated that it intends to use the power. We recommend that the Government bring forward proposals as early as possible in order to reduce the risk of pollution incidents from these sources.

9.29 The risk of pollution could be further reduced if the water regulatory authorities were given powers akin to those available to the Health and Safety Executive’s Factory and Agricultural Inspectorates. HSE inspectors are entitled to require preventive action to be taken where an evident risk exists to health and safety. We recommend that the water regulatory authorities be given powers, modelled on the provisions of the Health and Safety at Work Act, enabling them to inspect premises and issue improvement and prohibition notices where they identify significant water pollution risks. There may be premises, such as farms, where HSE inspectors could perform these tasks on behalf of the water regulatory authorities when visiting for health and safety purposes. Arrangements which facilitated this would be advantageous.

The European context for policy formation

9.30 Several international bodies are active in environmental issues, for example the UN-ECE in developing a critical loads approach to acid emissions control as described in paragraph 6.46. Government policy in respect of freshwater quality, as in many aspects of environmental protection, is increasingly determined by legislation negotiated in and adopted by the European Community. The impetus for progress in environmental protection in the Community has been established through a series of ‘action programmes’ on the environment, the fourth of which covers the period 1987–1992. These action programmes have led to Community directives aimed at protecting or improving water quality, in particular by setting quality objectives for water designated for specific purposes, such as abstraction for public supply, and by imposing controls over discharges to water of dangerous substances.

9.31 In 1986 protection of the environment was introduced into the Treaty of Rome as an explicit objective of the Community. Further amendment of the Treaty was agreed at last year's Maastricht summit so that the Treaty now requires environmental protection to be 'integrated into the definition and implementation of other Community policies' and requires the European Commission to base its proposals on a high level of environmental protection. The Treaty also now states that Community policy on the environment shall be based on the precautionary principle and on the principles of preventive action, of rectifying environmental damage at source and that the polluter should pay.

9.32 A seminar for European Community Ministers, held in Frankfurt in 1988, identified priorities for the development of EC water quality policy. Six areas identified were the need to:

- improve the ecological quality of surface waters;
- set standards for municipal waste water;
- accelerate measures for reducing the environmental impact of dangerous substances;
- give more attention to diffuse sources of pollution, particularly from intensive agriculture;
- address problems of water quantity as part of an integrated policy for water; and
- integrate water policy with other environmental policies.
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In November 1991, EC Ministers held a further seminar specifically to address groundwater problems and agreed on the need for the measures summarised in box 5.4. These seminars provide an agenda for action on water quality which bears a striking similarity to our own view of what is needed to protect and improve Britain's freshwaters. By playing a full and positive role in planning the subsequent action, and in the preparations for any further such meetings, the Government can help to ensure that soundly-based Community legislation is developed which will benefit both the UK environment and the Community as a whole.

9.33 The EC Commission has recently communicated to the Council proposals for a new Environmental Action Programme to start in 1993. It is intended to be a step in the development of a long-term strategy for sustainable development. We recommend that the Government, in contributing to the consideration of this programme and to the continuing development of policy for environmental protection, encourage the Community to:

- seek a high level of environmental protection, taking account of the different circumstances of Member States;
- ensure that Community policies in all relevant fields take environmental considerations fully into account;
- ensure that the best available scientific understanding is fully considered in framing Community legislation;
- take greater account of the costs and benefits of legislation for the protection of the environment; and
- develop a greater degree of openness and public accountability for environmental policy.

We consider each of these briefly below.

9.34 With further enlargement in prospect, increasing attention will be required to the variations in circumstances, problems and opportunities across the Community. In discussions we held with officials of the Dutch government, they raised the suggestion of developing regional environmental policies in order to reflect these variations. We have not considered in detail the advantages and disadvantages of this idea. Clearly, environmental policies must be sufficiently flexible to recognise differences in ecosystems resulting from such factors as geography and climate. Differences in economic development and in priorities for allocation of financial resources may also need to be recognised and taken into account. They may affect the speed with which environmental improvements can be achieved in some places and may call for longer periods of implementation and for financial assistance. This need not, however, affect long term aims or risk giving the impression that some environments and their inhabitants are less worthy of protection than others.

9.35 A policy of uniformly high standards, albeit recognising geographical differences and tolerating different timescales for implementation, needs to be distinguished from a policy of requiring uniform solutions to environmental problems. Indeed, efficiency in achieving high standards is likely to be improved by a policy which encourages diversity in solutions to problems. One of the benefits of economic instruments such as the charging scheme we propose in chapter 8 is that they encourage dischargers to seek solutions that are most efficient for their circumstances. Arrangements that encourage a variety of ideas and innovations are likely to lead to more efficient ways of solving problems. We recommend that, in working for a high level of environmental protection, the Government should encourage the Community to adopt policies which will allow diversity and innovation in solutions to flourish.

9.36 Consideration of the environmental aspects of all policy areas is increasingly recognised as an important means of protecting and improving the environment. In evidence to us the European Commission said that there was increasing co-operation between the Directorates General of the Commission responsible for agriculture (DGVI) and for the environment (DGXI) and that the aim of reducing agricultural surpluses offered opportunities for reducing adverse environmental effects from agriculture. We welcome the efforts the European Commission is making to integrate environmental issues into other policy areas. This was also a strong theme of
the Government's White Paper in 1990\textsuperscript{38}. We recommend the Government use the experience it has gained from its own initiatives to support further moves in this direction within the Community. Industrial, transport and energy policies all affect water quality but the Common Agricultural Policy (CAP) is most frequently singled out as requiring a greater sensitivity to water quality issues. To a large extent farming practices are a response to the financial signals that farmers receive from the CAP and elsewhere. As the Community addresses the problem of agricultural surpluses, the opportunity should be taken to introduce financial signals that will work to the benefit of the environment. We recommend that the Government encourage moves in that direction. We are pleased to note that the Government has stated\textsuperscript{39} that it is pressing for environmental considerations to be taken properly into account in CAP changes.

9.37 Both the EC Environmental Action Programmes and the amended Treaty of Rome refer to the need to take account of available scientific and technical data in determining Community action on the environment. In preparing new environmental proposals, the European Commission usually convenes groups of national or other experts, employs consultants and holds seminars. It has recently embarked on the publication of a series of books containing much of the background material collected in this way. Proposals put to the European Parliament and the Council of Ministers by the Commission are not, however, always supported by documents which explain the technical, scientific and other merits of the proposals or which outline the views which are common to the majority of experts and any dissenting opinions. Political pressures influence all stages of the legislative process, especially in the Council of Ministers and Parliament. The process would be improved and there could be more informed debate of the merits of the Commission's proposals if the Commission published, with its proposals, summaries of relevant material obtained during preparatory work. We recommend that the Government encourage the Commission to do so. This would help to establish an 'audit trail', the importance of which we emphasised in our Twelfth Report on the best practicable environmental option. The Science Working Group of the Intergovernmental Panel on Climate Change has recently provided an example\textsuperscript{40} of how this can be done successfully in its statements about the differing degrees of confidence which the Group had reached on various propositions. The World Health Organisation has long had a practice of publishing the bases from which its guidelines have been derived.

9.38 Equally important is the need to ensure that Community policies and legislation are reviewed in the light of developments in scientific knowledge. We comment in chapter 7 on the need to revise limits in the drinking water directive. Within the EC it has now become common practice for environmental directives to include provision for the establishment of committees to advise on detailed aspects of the implementation of directives and, sometimes, to review them as scientific understanding advances. We recommend that, in discussing proposed new directives, the Government should seek to ensure that they always contain the necessary flexibility for review in the light of new scientific knowledge or in other relevant circumstances. Many directives agreed before the mid-1980s contain no provision for expert committees. Proposals by the European Commission to establish a committee procedure which would have enabled such directives to be reviewed and amended have not received the support of the EC Council of Ministers. It is nevertheless desirable that a formal procedure for review should be established. We recommend that the Government encourage the European Commission to develop proposals which would secure the support of the Council of Ministers.

9.39 As noted in chapter 8, the implementation of policies to improve water quality imposes costs, which may be substantial. It is essential, therefore, to analyse those costs in relation to the benefits. The European Commission has introduced a system of financial 'fiches', attached to proposals for legislation, which comment on the likely cost of the proposed measures to business. This is a step in the right direction, but should be developed further. We understand that the Government has pressed for EC legislative proposals to be subject to full cost-benefit analyses. It is by no means simple to quantify the benefits, or even necessarily the costs, of environmental legislation. The European Commission has nevertheless undertaken\textsuperscript{41} to strengthen its 'fiche' system to take account of costs and benefits to the Member States' public authorities and all the parties concerned. We welcome this undertaking.
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9.40 Under an EC directive, adopted in 1990 and which must be implemented by the end of 1992, member states must ensure that public authorities are required to make information relating to the environment available to any person. They must also provide general information to the public on the state of the environment by such means as the periodic publication of descriptive reports. These are valuable developments, which we welcome. The Government, following a recommendation in our Tenth Report, has established a system of public registers on many aspects of environmental pollution. In paragraph 9.45 we recommend that this be supplemented by the introduction of national and Community-wide registers of emissions. In addition, we recommend that the Government encourage the Community to develop a mechanism for reviewing the progress which has been made in achieving environmental aims. This would include progress in achieving formal compliance with directives, their enforcement in practice and improvements in certain key aspects of the environment. Many of the elements required for this are already in place, including the directive referred to above, but they need to be developed and brought together. The review procedure should include meetings open to the press and to non-governmental organisations, thus enhancing the public accountability of EC environmental policy.

A perspective for the future

9.41 As noted in chapter 1, the precautionary principle has become widely accepted internationally as a basis for environmental policy. It is generally applied in relation to toxic pollutants which are persistent or bioaccumulative and to those which seem likely to fall into that category. At the same time, there is a long-standing view that it is acceptable and sensible to make use of the assimilative capacity of the environment. Such a view is widely held in relation to water pollution control and we refer in several places in this report to the purifying capacity of rivers. Much effort is being devoted to substituting biodegradable chemicals for persistent ones which might be released to the environment. This is welcome but it must be recognised that biodegradation also affects the environment by encouraging the growth of organisms that perform the degradation. As explained in chapter 3, some biodegradable wastes are pollutants not because of their toxicity but because of the heavy oxygen demand of these organisms. Use of the environment to dispose of wastes in this manner therefore also has to be carefully controlled.

9.42 Increasingly, new attitudes towards the discharge of wastes are being developed. The German Council of Environmental Advisers, for example, in a recent report on waste management, proposed the development of a waste avoidance strategy. The Council told us that it advocated:

— Minimisation of waste creation; processes should be designed so that they produce as few waste products as possible.

— Recycling and reuse; wastes should be separated to facilitate recycling and reuse of as much of the waste as possible, subject to the energy cost.

— Composting; biological waste that cannot be recycled or reused should be composted to produce usable products, such as methane and fertiliser.

— Conversion to inert forms; what is left should be converted, probably by incineration, to a biologically inert form which is suitable for land-filling.

The Council took the view that any other approach risked damaging the environment. Some major German companies are aiming to dispose of only inert material from their premises.

9.43 The policy described above was developed in the context of the generation and disposal of solid waste. Policies are also being developed to reduce pollution more generally. Many major companies, including some leading British firms, have announced their intention to cut levels of pollution substantially. The Confederation of British Industry told us it has established an Environment Business Forum, a network of organisations committed to the pursuit of environmental excellence in achieving a competitive advantage. The United States Environmental Protection Agency publishes each year a 'Toxics Release Inventory' (see box 9.5) listing the total quantities of specified substances emitted by each manufacturing facility in the country above a threshold size. The Agency told us that the resulting publicity has helped to create a
climate of opinion in industry in which meeting the legal limit of emissions is perceived as the minimum response and efforts are made to improve significantly upon the limit. It has established a ‘33/50 programme’ of companies which have voluntarily committed themselves to making reductions of 33% and 50% in their emissions by certain target dates. At least one major company has committed itself to a 90% reduction in emissions, worldwide.

**BOX 9.5 TOXICS RELEASE INVENTORY**

In 1986 the US Congress required the establishment and maintenance of a Toxics Release Inventory. The Inventory, which is the responsibility of the Environmental Protection Agency (EPA), is a record of emissions of toxic substances specified in a list. It applies to all manufacturing facilities above a threshold size (10 employees) and which handle any listed substance in quantities above an appropriate threshold. 307 substances are listed but most facilities handle only one or two of them. Companies are required to report, each year, the quantity of each listed substance that is released as waste in any form or as part of their products.

Information previously available to the public was considered inadequate. Information on discharges to water, for instance, was expressed in categories such as BOD, rather than for specific substances; it often covered only consented levels but not actual discharges, or concentrations in samples but not annual totals. The format of the information differed for each medium. No information was available on the amount of each substance entering the site or leaving in products.

The information for the Inventory is provided in a single, specified format for all substances and all media. It is collated by the EPA and displayed in local, state and national tables and maps as well as for individual sites. Local and national newspapers have made extensive use of the information provided, leading to public pressure on companies to reduce releases of toxic substances.

9.44 We consider that progressively less reliance should be placed on the environment as a mechanism for processing anthropogenic waste. The question of how much waste can be disposed of to the environment without adverse impact should be preceded by asking how far the pollution from a process can be reduced. This would require two changes to policy for the protection of the aquatic environment, which we recommend. The water quality objectives approach should increasingly be supplemented by technology-based emission limits, tightened progressively in accordance with BATNEEC, such as are now used for the control of discharges of Red List substances, described in appendix 4. Secondly, the objectives themselves should be tightened progressively, to reflect increasingly ambitious targets for water quality, and consented discharge levels be reduced accordingly. In this way a process would be established which would lead to progressive reductions in pollution. It would enable advantage to be taken of advances in technology and would provide a means of responding to increases, as national wealth rises, in the value the public attaches to the environment and to its protection for future generations. It would thus recognise that the best practicable environmental option for the disposal of wastes changes as technology develops and the value placed on the environment increases.

9.45 Further, industry should be encouraged to reduce all emissions, beyond what is required by law. As an immediate step towards this, we consider that a programme based on the US Toxics Release Inventory could usefully be developed in the European Community and we recommend that the Government urge the Community to introduce it. This would be a suitable task for the new European Environment Agency. It should apply to all significant polluting activities, not only those involving manufacture. The adoption of economic instruments such as those described in chapter 8 for discharges to water would also help to reinforce the required change of attitude, both by making it clear that polluters should pay for the harm that they cause and by providing a continuing incentive for investment in abatement equipment and in cleaner technology.

9.46 The activities of earlier generations provided an inheritance for this generation, an inheritance of wealth but also of environmental degradation. In the same way, the activities of today will leave a legacy, of good and ill, to future generations.
CHAPTER 10

SUMMARY AND RECOMMENDATIONS

Recommendations are shown in bold type, together with the paragraph of the main text from which each is drawn.

Introduction

10.1 The control of inputs of polluting substances to inland waters has a long history in the UK. Substantial pollution of inland waters has nevertheless taken place. In recent years, water quality issues have received increasing public attention. The river quality surveys for England and Wales in 1985 and 1990 recorded a net deterioration over the past decade in contrast to the improvements recorded over the 20 years up to 1980. In Scotland the surveys have shown continuing improvements. Prior to the privatisation of the water industry in England and Wales in 1989, the Government announced a major investment programme by the industry, estimated to cost £28 billion over 10 years, partly aiming to meet European Community requirements.

10.2 Most of the 17 million cubic metres of freshwater abstracted daily for public supply in England and Wales is returned to rivers. To some degree, rivers have a natural purifying capacity through the action of microorganisms, sunlight and physical aeration. The need to use rivers for discharge of effluents nevertheless carries with it an obligation to consider carefully how to keep adverse impacts to a minimum.

10.3 It is essential to ensure that the quantity and quality of water resources are not only able to meet present needs but will also be likely to meet future needs so far as these can be foreseen. Future generations should have access to water resources which will allow them no less, and preferably a greater, range of options than are enjoyed today. This sustainable use approach requires policies with the following elements:

- There is a need to develop reliable ways of monitoring the quality of freshwaters and the condition of communities of plants and animals which depend upon them.

- Plans need to be developed to ensure that the required quantity and quality of water resources are maintained, so that meeting today's demands does not reduce the future availability of the resource.

- Processes which give rise to a cumulative long-term deterioration of freshwater must be brought under firmer control.

- The costs of improvements in water quality should be evaluated in relation to their benefits, including benefits to future generations.

- A precautionary approach to pollution control should be maintained.

10.4 Freshwaters have many uses and these can be in conflict with each other. Resolving such conflicts is an essential part of the process of controlling water pollution and, more generally, of managing water resources. A framework for making such judgments must incorporate rational criteria, public involvement and proper accountability.
Summary and Recommendations

10.5 Measures to protect water quality might have adverse side effects on other parts of the environment. Equally, measures to protect land or air should be assessed for their potential impact on water quality. A commitment to the achievement of the best practicable environmental option (BPEO) should be a cornerstone of water policy.

Chemical and biological characteristics of freshwaters

10.6 The supply and renewal of fresh water in the environment is driven by the water cycle. As water moves through the cycle its chemical characteristics are affected by contact with substances in the atmosphere and in soils. The biological character of freshwaters is dependent on the physical and chemical characteristics of the water.

The impact of pollution and water use

10.7 The impact of pollutants on freshwater depends on their chemical, physical and biological properties, their concentrations and the duration of exposure. Pollutants which exert a large oxygen demand during degradation can harm aquatic life through oxygen depletion. Other substances of concern include those which are toxic and either resistant to degradation (persistent) or able to accumulate in organisms (bioaccumulative) or both.

How water quality is assessed

10.8 Freshwater monitoring may involve examining physical, chemical and microbiological characteristics of water samples or sampling the flora and fauna of waterbodies. The two approaches are complementary and one will often compensate for deficiencies in the other. The objectives of monitoring schemes must be clearly defined and programmes devised to achieve an acceptable degree of statistical reliability. General classification schemes have been devised to present a broad picture of the state of rivers and other waters. The most meaningful way to do this is to move as close as possible to monitoring the aquatic biota. We recommend, therefore, that the regulatory authorities should endeavour to develop a general classification scheme based on biological assessment for use throughout the UK in the 1995 and subsequent river quality surveys. (4.26) We also recommend that the regulatory authorities should move towards a system of reporting results volumetrically as well as by length. (4.27)

10.9 Physical, chemical and microbiological determinands must continue to be monitored in order both to explain changes in the biological indices and to meet the particular needs of water quality managers. To explain changes in the biological state of a river, we recommend that a wider set of determinands should be developed than the three main ones in the NWC and NRA classification schemes. They should include data on nitrate and phosphate, on microbiological indicators and on the presence of heavy metals and key pollutants such as pesticides. (4.28) Presentation of the levels of, and trends in, the separate determinands would be valuable. Data on these determinands should be published more frequently than the quinquennial biological assessment, perhaps annually.

10.10 The basis for this exists in the Harmonised Monitoring Scheme. We recommend that the Government should convene a working party which
includes representatives of the NRA and RPAs to consider the objectives of the scheme and to develop means of achieving these aims. The working party should also review the coverage of sites and determinands and the addition of biological monitoring and should consider the best way of presenting the information to the public. (4.34)

Recommendation 5

10.11 We recommend that small watercourses should be monitored from time to time (perhaps using rapid biological screening methods) and action taken to remedy any problems revealed. (4.37) We recommend that UK standing waters of 0.4 hectares and above should be surveyed and classified on a regular basis and that as far as possible the classification should adopt an internationally recognised system such as the OECD one. We recommend that Government should encourage research into development of biological indicators using similar principles to RIVPACS. (4.39) We welcome the National Pond Survey initiated by Pond Action. (4.40)

Recommendation 8

10.12 The NRA has recently published its proposals for the setting of statutory water quality objectives (SWQOs). We recommend that the general biological classification scheme should be used to set a biological SWQO. (4.44) We agree with the NRA's proposal that quality objectives be set for standing waters above 0.4 hectares so that deterioration in their quality can be prevented or reversed. In some cases achievement of SWQOs may require longer than 5 years. SWQOs need to be set within a framework of catchment management plans enabling longer term plans to be developed.

Recommendation 9

10.13 We recommend that the Government should draw up water policy plans for the UK, setting out appropriate targets as well as the timescales and means of reaching them. (4.50) We recommend that, as a priority, ways of improving the remaining class 3 and 4 stretches of water should be identified, discussed with those responsible and costed so that action plans can be agreed to improve them over a realistic but challenging timescale. At the same time, everything should be done to prevent deterioration of high quality waters. The SWQOs for class 3 and 4 rivers should be set so as to achieve the targets in the action plans. The plans should be made public and progress monitored. (4.51)

Recommendation 11

Groundwater

10.14 Groundwater is vulnerable to pollution from diffuse and point sources. We recommend that the Government consider with local and public health authorities whether adequate monitoring of private boreholes, springs and wells is being carried out and adequate advice offered to users. (5.10) Monitoring of groundwater quality has concentrated on samples from abstraction boreholes. There is no groundwater equivalent of the regular national survey of surface water quality. We understand that the NRA is currently developing proposals for a national network of groundwater observation points and we welcome this. We consider it desirable for the network to give a representative, though not necessarily fully comprehensive, picture of the state of groundwaters in aquifers throughout the country. Subject to this the construction of additional boreholes for the network should be kept to a minimum.

10.15 The quality of water abstracted from boreholes remains high. Surveys of aquifers under urban and industrial areas, however, have revealed extensive pollution from solvents. In the absence of a national survey there can be no confidence about the state of groundwaters across the country. The
limited capacity of groundwaters for self-purification and the difficulty of
decontaminating aquifers mean that elimination of all polluting impacts
should be pursued as an immediate policy aim. We welcome recent proposals
by the NRA to apply consistent policies in future across England and Wales
for regulation of indirect discharges to groundwater. Controls over activities
which may contaminate land over aquifers are less well developed and
haphazard in their operation. The problems of the legacy of polluted sites
have scarcely begun to be addressed.

10.16 EC Environment Ministers agreed last year a declaration on
groundwater protection proposing an action plan to protect and improve
groundwater. We urge the Government to make a positive contribution to
the development of this programme. The NRA has recently published
proposals to protect groundwater including surveys of aquifers and policies
on the acceptability of potentially polluting activities. We recommend that
the NRA and its counterparts in Scotland and Northern Ireland seek to define
SWQOs to safeguard the quality of rivers and lakes fed by groundwater and
ensure maintenance of groundwaters free of polluting inputs. (5.24) We also
recommend that the approach the NRA is developing to improve protection of
groundwater be extended to Scotland and Northern Ireland. (5.25) We believe
that valuable benefits will be obtained from the proposed measures to survey
aquifers to identify their vulnerability, to extend and develop aquifer
protection policies and to make better use of the powers that exist to protect
groundwater, in particular powers to designate water protection zones. We
see a need for further work to address the problem of the legacy of contaminated land. We recommend that the Government seek ways of increasing the resources available to clean contaminated land in order to
protect groundwater. (5.25) Where sites are in use or being redeveloped
occupiers and developers should be encouraged to develop programmes of
improvement, assisted where appropriate by public funds.

Eutrophication

10.17 Natural inputs of plant nutrients to water are frequently supple-
mented by inputs from agriculture, sewage effluents and other sources.
Limited enrichment of nutrient-poor waters may bring an increase in the
abundance and variety of plants and animals but at the expense of species
which are only found in nutrient-poor waters. Heavy enrichment can reduce
diversity of species and favour growth of algae and some toxin-producing
species. The levels of phosphate revealed by monitoring suggest that many
rivers and lakes in England are heavily enriched. However, action to reduce
inputs of nutrients to water has been taken in only a few selected places.
Quality objectives need to be established for standing waters as well as for
rivers since it is in lakes and reservoirs that nutrient enrichment often
presents the most difficult problems. The NRA's consultation paper on
statutory quality objectives proposes such an extension and we recommend that
this should be implemented. (6.15) The present range of quality objectives
needs extending to take fuller account of the conservation and amenity issues
raised by nutrient enrichment, both in standing and flowing waters. Quality
objectives are required which enable the desired ecological state of waters to
be expressed. We recommend that, in implementing its proposals along these
lines, the NRA should ensure that the objectives are defined in ways which
enable the ecological impact of nutrient enrichment to receive attention. (6.15)
The water quality standards that are associated with quality objectives need
to be extended to cover nutrient levels, taking account of factors such as flow
and temperature which also influence the trophic state of the water.
10.18 In setting such objectives it will be necessary to consider to what extent it is desirable or practicable to restore waters to the eutrophic state that obtained prior to significant enrichment as a result of human activities. Where such a state can be identified, we recommend that it should form the long term target for flowing and standing waters. (6.16) In cases where it will not be practicable to achieve this target in the foreseeable future, or where such a baseline state cannot be identified, we recommend that quality objectives are set to secure conditions achieving an acceptable level of both species diversity and amenity. (6.16) The existing widespread occurrence of eutrophic and hypertrophic lakes and reservoirs is not, in our view, desirable. Rivers that exhibit symptoms of excessive weed growth, siltation and other deleterious effects associated with enrichment are similarly undesirable. Equally, enrichment of nutrient-poor waters of conservation value should be avoided. We recommend that the Government should take these views into account in considering the criteria to adopt for designating sensitive areas under the EC's urban waste water treatment directive. (6.18)

10.19 Reversal of the effects of enrichment is likely to require removal of nutrients from effluents on a significant scale. We do not favour the adoption of a single national target figure for nutrient levels in freshwater in the UK, preferring to approach the issue through water quality objectives related to the needs of each body of water. We recommend that the Government work with the water industry and regulatory bodies to ensure that promising methods for phosphate removal are developed. (6.19) Eliminating the phosphorus load from detergents could make an important contribution to reductions in concentrations in surface waters where stripping at sewage works is not practicable. We recommend however, that caution should be exercised in replacing phosphate in detergents until the environmental effects have been fully evaluated and found to be acceptable. (6.21) We recommend that the Government consider with detergent and washing machine manufacturers whether it could be made easier for consumers to take advantage of the fact that less detergent is required for washing in soft water than in hard to reduce their use of phosphate. (6.21) Nutrients other than phosphorus may also need to be controlled and reductions in phosphorus inputs from sources other than sewage works may be needed. A recent NRA report contains relevant recommendations including a review of discharge consents for farm effluents, the development of risk assessment procedures for catchments and investigations to test the value of buffer zones alongside watercourses. We consider that these recommendations merit support.

10.20 Reduction of inputs of nutrients may not by itself always be sufficient to enable enriched waters to recover. Sediments may continue to provide a source of phosphate. Techniques to deal with this can be extremely costly. The polluter pays principle would suggest that the cost of remedial works and, indeed, the cost of reducing new inputs by phosphate stripping and other means, should fall on those who are responsible for introducing phosphorus into the environment. No single solution of problems of nutrient enrichment is likely to be applicable throughout the country. We endorse the conclusion of the House of Lords Select Committee that 'integrated strategies . . . . be established on a site by site basis' and we so recommend. Catchment management plans offer a framework for doing this.

Acidification

10.21 Some soils and freshwaters are acidic as a result of naturally-occurring processes. However, in many places natural acidity has been enhanced by the deposition of acid gases and particles emitted by industrial processes and vehicles, and by changes in land use. Most UK aquifers used to
Supply drinking water are well buffered and therefore not vulnerable to acidification. This is not the case for certain shallow groundwaters. We recommend that the Government ensure the effects of acidification on unbuffered groundwaters are assessed. (6.32) Under certain conditions, coniferous forests can significantly increase local deposition of sulphur and nitrogen. We consider that the Forestry Commission’s revised guidelines on forests and water and the requirements for environmental assessment provide a firm basis for reducing adverse effects of forestry on water quality. The incorporation of appropriate policies in indicative forestry strategies would bring further improvements. We consider, however, that the Forestry Commission’s guidelines appear to place too much reliance on liming to mitigate the effects of acidification. We view liming as a short term ameliorative measure, not as an alternative to prudent land use practices. We consider that it may be necessary to restrict planting in some sensitive catchments and we recommend that the Forestry Commission incorporate advice to that effect within its guidelines. We also recommend that water regulatory authorities, in developing their catchment management plans, should incorporate appropriate policies for afforestation on sensitive catchments including guidance on locations where it might be necessary to restrict planting. We further recommend that local authorities and national park authorities reflect such policies in their indicative forestry strategies. (6.43)

10.22 The acidity of freshwaters can be reduced by the addition of powdered limestone or chalk to soils or by liming the water directly. We consider that liming should only be regarded as a short-term ameliorative measure and should be used in conjunction with, rather than as an alternative to, efforts to reduce acid emissions and to change land use practices which exacerbate the impact of acid deposition. We support the NRA’s view that liming should be restricted to suitable sites which will derive the maximum benefit. We recommend that liming programmes should incorporate arrangements to monitor their impact. (6.45)

10.23 It is doubtful whether the reductions in acid emissions agreed thus far by the Government will be sufficient either to secure a satisfactory reduction in the damage caused in the UK by acidification, or to meet the needs of other countries which suffer from acid deposition. We recommend that the Government should seek in these international negotiations, agreement on a long term aim of reducing acid emissions so that the critical loads are not exceeded in the UK and elsewhere in Europe. This should be done in the most cost-effective manner and to an agreed timetable which takes due account of the environmental damage that is being sustained and the costs and practical difficulties of achieving emission reductions. We recommend that the best practicable environmental option should be considered in selecting the appropriate reduction methods in order to achieve an outcome which is most favourable to the environment as a whole. (6.53) We also recommend that the Government should increase the resources it allocates to research on clean fuels and the opportunities for renewable energy developments. (6.53) Consideration of the impact of acid emissions from motor vehicles is also required.

Waste water production and treatment

10.24 Although most domestic sewage is biodegradable some of its constituents are not. We recommend further research on the extent to which metals from domestic sources are reaching the environment. If household sources are found to be significant, their contribution will need to be reduced. (7.7) We recommend that an exploratory study be carried out into the presence of other substances — such as constituents of cosmetics, toiletries and medicines — in river waters and of their environmental effects. (7.8)
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10.25 Complex industrial discharges are difficult to monitor and control under the normal system of consents. Regular programmes of biological monitoring may help draw attention to unrecognised pollutants and unsuspected effects. An approach increasingly in evidence is to move towards better selection and control of processes, recycling and treatment within each industrial plant, with a view to minimising waste and reducing its environmental impact; we welcome this.

Recommendation 33

10.26 We recommend that, where receiving waters are sensitive to pollution, the regulatory authorities should replace the descriptive consents for effluent from small sewage treatment works (STWs) with numerical ones. (7.23) We recommend frequent regular visits by peripatetic operators, who can rectify faults on the spot, in order to minimise periods of unsatisfactory operation. (7.24) We also recommend that more consideration should be given to improving the design of small STWs so that they provide effective and reliable treatment. (7.24)

Recommendation 34

10.27 It is clear that, for most of this century, the financial circumstances under which local authorities and then water authorities operated, played an important role in determining the quality required of sewage works’ effluent. There has been a serious lack of investment going back many years. The position was exacerbated by non-compliance with consent conditions, to which hydraulic and biological overloading, poor operation and maintenance, and design of sewage treatment works all contributed. Where non-compliance is caused by industrial discharges to sewer, the sewerage undertaker should either revise the trade effluent consents or enforce them properly. For many treatment works, a fundamental review of operational practices and maintenance experience will be necessary. We recommend that where casual training methods still persist, they should be superseded by formal training schemes leading to nationally accepted proficiency standards recognised by the award of a certificate. (7.34) Adequate manning levels are also required. Design is also an important factor. We recommend that when extensions or changes to works are contemplated, the whole treatment process should be subjected to rigorous analysis so as to minimise unforeseen effects and optimise the value of the investment made. (7.35)

Recommendation 35

10.28 The measures which have been initiated to control pollution from sewage works may be no more than a first step. More will be required to cope with future growth, tighter standards and to maintain compliance at existing STWs in the longer term. Special treatment may be needed of substances which are not rendered harmless by the normal operation of the STW or by natural biodegradation. Further expenditure may also be needed in order to remove nitrate and phosphate, especially from effluents discharged to any waters designated as sensitive under the EC urban waste water treatment directive. We recommend the application of nutrient reduction to STWs regardless of their size if the condition of the receiving waters merits it.

Recommendation 36

10.29 Improvement in the quality of freshwater has been impeded also by defects in the way both industrial and STW discharge consents have been set and enforced. We consider, however, that, when fully implemented, the NRA’s new policy on these will resolve much that is unsatisfactory. We recommend that suspended solids limits should be determined by reference to the nature of the effluent and the quality objective of the receiving waters. (7.42).

Recommendation 37

10.30 Some severe river pollution occurs from separate sewerage systems whenever rainwater drains from highways and paved areas. We recommend that a radical reappraisal be undertaken of the polluting effects of untreated, intermittent surface water discharges from such systems. (7.45) Pollution also results from overflows on combined sewers which are designed to spill excess
flows at times of heavy rain. Poor sewer and overflow design, and failure to
invest to cope with increasing flows have contributed to this. We welcome
modelling studies to help identify cost-effective improvements and develop-
ments to link overflow operation to riverine quality objectives. We hope for
the speedy completion of the development programme and the adoption of
its results by sewerage undertakers. We would support further development
of control systems for sewerage systems provided they can be made
sufficiently robust. High priority will be needed in water quality plans for
measures to remedy unsatisfactory overflows. In the meantime, short-term
improvements should go ahead unabated and with all urgency.

Contaminated land

10.31 Soil has a limited capacity to absorb, degrade or attenuate the effects
of pollutants. When this capacity is exhausted polluting substances may be
leached into surface and groundwater. Recently the Government has
couraged the use of remedial techniques. We recommend that the
Government investigate the potential environmental long-term impact of the
use of naturally-occurring micro-organisms in such techniques and consider
whether controls are needed. (7.60)

10.32 The major threat to freshwater quality from landfill leachate. The
Environmental Protection Act 1990 provides the opportunity to require
monitoring of leachate production and migration; we recommend that such
monitoring should be required for all landfill sites. (7.64) In our Eleventh
Report we recommended that reliance should never be placed on the long-
term containment of leachate, which should be extracted and processed so
that containment failure cannot lead to pollution of an aquifer. We are not
aware of any evidence that would lead us to change this recommendation.
We support the recommendation by the House of Commons Environment
Committee that "the use of synthetic liners should be subject to stringent
degradation and transmissivity criteria and quality control and that their
design should be subject to approval by the authority controlling the
underlying aquifer". We recommend that Government guidance on the
pollution threat from closed landfills should encourage monitoring of leachate
production and movement from the site and emphasise the importance of
ensuring that results from this monitoring are taken fully into account in
determining whether a pollution threat continues to exist. (7.66)

10.33 When mines close or are abandoned the flow of water in them is
usually no longer regulated. In coal mines which contain iron pyrites ore this
can lead to the production of ferruginous discharges. We recommend that the
regulatory authorities should review all consents for operational mines to
ensure that, where possible, conditions are imposed requiring action to be
taken in the event of closure to safeguard water from pollution. The authorities
should also review mines which have already been abandoned, identify any
which pose a water pollution risk and develop a programme of action to reduce
the risk. (7.70) We recommend that the Government consider ways of
remediating the apparent absence of legal powers to require owners or former
operators of abandoned mines to prevent pollution. We further recommend
that, where the owners of the sites are unwilling or unable to carry out work to
reduce the risk of pollution, the authorities should seek from the Government
the support and the necessary funds to have the work carried out. (7.70)

10.34 The imposition on china clay quarries of discharge consents with low
suspended solids limits and the use of settlement lagoons has had a marked
effect in reducing the industry's impact on the aquatic environment. We
recommend that the NRA continue to seek improvements. (7.73)
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10.35 The Environmental Protection Act 1990 places a duty on local authorities to complete and maintain registers of land which is being or has been put to a 'contaminative use'. We note with regret that the Government has found it necessary to defer the introduction of these registers. If, as we understand, it is not intended that the registers should include details of wastes discharged into former underground mine workings, we recommend that the Government reconsider the position. (7.74)

10.36 Guideline figures, called 'trigger values', are used to assess a site's suitability for development or to what degree it must be cleaned up. These guideline values do not take any account of the risk to groundwater. We recommend that the Government develop appropriate advice on trigger values for sites which may pose a risk to surface or groundwaters. (7.75)

Transport

10.37 Designers of road construction projects should not overlook the pollution risks that may arise during both construction and use. Liaison during the design stages with the appropriate pollution control authorities will help to reduce risks. We recommend that the Government encourage research on road drainage systems to reduce pollution and provide the stimulus for any promising systems to be developed and tested. (7.79) We recommend that the Government review its advice to highway authorities to ensure that their attention is drawn to the need for drainage systems to be of an adequate size to cope with likely pollutant loads and to be regularly emptied and maintained. (7.79)

10.38 We recommend that the water regulatory authorities encourage users of aircraft and runway de-icing agents to carry out trials of alternative products which are claimed to be less polluting. If the trials are successful we recommend the authorities require the use of these alternatives in place of more damaging formulations. (7.81) The authorities should also ensure that run-off is properly collected and, where appropriate, treated before discharge.

10.39 Frequent monitoring of the condition of pipelines and the use of additional pipe protection measures would help to reduce the risk of pollution.

Farming

10.40 Recent changes to reduce agricultural pollution are welcome but they do not address the fundamental imbalance that can exist between the scale of livestock units and the capacity of nearby land to take the wastes produced. The approach to be taken to this imbalance should be consistent with the industrial nature of intensive livestock production. We recommend that operators of intensive livestock units above a specified size should be subject to an authorisation system operated by the agriculture departments. Authorisation should be granted only where the operator has adequate storage and disposal arrangements. Advice on disposal techniques should be provided by ADAS. (7.99) We recommend that, in considering applications for authorisation, the agriculture departments should act in consultation with the NRA/RPAs but should also take account of all risks of nuisance and environmental pollution, not only those relating to water. The Government should periodically review the workings of the authorisation scheme and consider reducing the size qualification if problems still occur with smaller units. (7.99) The scheme should be complemented by flexible powers enabling the pollution control authorities to require, at the expense of the potential polluter, preventive action to be taken to reduce the risk of water pollution. (7.103)
10.41 We support the NRA's proposal for the development of a national strategy for agricultural waste management, to be implemented through individual farms plans whose adoption should be a pre-requisite for grant support for pollution prevention measures. We recommend that such a plan should be a requirement of the authorisation scheme proposed above for large livestock farms. (7.101) We recommend that the Government should take the lead in investigating with farming interests the scope for encouraging technology for converting slurry into gas and fertiliser or sanitised slurry, and should make financial support available for suitable projects. (7.102) We recommend that the Government should ensure that ADAS actively seeks opportunities to offer advice on pollution control, free of charge wherever possible, and that it has sufficient resources to do so. (7.104) The Government should ensure that the Farm and Conservation Grants Scheme provides an adequate incentive to improve waste management systems in Less Favoured Areas since these contain many vulnerable waters; and that livestock slurry treatment plant should be eligible for grant aid when proposed by cooperatives. (7.104) We welcome the collaborative approach between ADAS and the NRA, linking advice and education with a firm policy of prosecuting the small minority of farmers who carelessly or irresponsibly cause serious pollution incidents.

10.42 Silage is one of the most potentially polluting farm wastes. We welcome the research in progress which aims to understand all the mechanisms involved.

10.43 More research and development is required in order to improve waste removal technology for cage fish farms. We recommend that cages should be sited in a manner and position consistent with the efficient dispersal of waste. They should not be permitted where this cannot be satisfactorily achieved. In addition the pollution control authorities should ensure that they use to the full their powers to limit discharges from fish farms so as to prevent adverse effects. (7.110) We consider that the authorisation system recommended above for operators of large intensive stock units should extend to fish farming.

10.44 Farmed fish are reared at a high stocking density and are susceptible to a wide range of diseases. We recommend that the long term fate and environmental effects of veterinary medicines should be more extensively studied. (7.111) We recommend that consent conditions should be set for antibiotics and other biologically active chemicals in effluents from fish farms. (7.113) Further research may be needed to establish standards to protect the environment and public health. To minimise the transmission of disease from farmed fish to native stocks, the highest standards of hygiene are essential at all stages of the fish rearing process and in the movement of fish stocks. There is also a need to improve understanding of both the transfer of disease between farmed and wild stocks (and vice versa) and the survival time of pathogens in water. There appears to be scope for a fuller understanding to be developed of the genetic transfers between farmed and wild fish stocks.

10.45 We recommend that the authorities ensure speedy and effective action to monitor the watercress industry and to establish consents to control pollution from it. (7.118)

Nitrate

10.46 The main concerns arising from the concentration of nitrate in freshwater relate to its properties as a plant nutrient and its possible impact on health as a drinking water contaminant. We have seen little evidence that
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elevated levels of nitrate alone have major effects on the freshwater environment. With regard to human health, a substantial intake of nitrate can contribute to the development of methaemoglobinema in infants under six months but other factors are important and the disease is extremely rare in the UK. There appears to be no epidemiological evidence that the concentrations of nitrate in water in the UK are associated with an increased risk of cancer. We have not been convinced that the strict limit in the EC drinking water directive is needed to safeguard health in the UK or in any other country with a satisfactory public water supply system. We regret that the EC limit has created anxiety in the minds of consumers whose supplies are known to be marginally in breach of the limit, has removed from use several water sources which were regarded as secure, possibly diverted resources and attention from more deserving objectives, and created some environmental problems in disposing of nitrate removed from supplies.

10.47 Nitrate's role in the nutrient enrichment of fresh, and eventually sea waters, coupled with the EC nitrate limits for drinking water, make it unacceptable for levels of nitrate in freshwaters to continue to increase. Action is needed to stop the rising trend and, preferably, secure a reduction in the worst affected waterbodies. We welcome the recent agreement in the EC to a directive on the protection of fresh, coastal and marine waters against pollution caused by nitrate from diffuse sources. We also welcome measures taken by the UK Government to reduce nitrate pollution and consider it important that maximum benefit is obtained from them in implementing the new directive. If the pilot Nitrate Sensitive Areas scheme demonstrates potential to reduce nitrate pollution cost-effectively, its lessons should be rapidly applied, for example in implementing the further measures envisaged in the nitrate directive.

Pesticides

10.48 Pesticides enter the aquatic environment from many sources. There is evidence that some pesticides can be transported in the atmosphere over considerable distances. We welcome work commissioned by DOE to identify both the degree and sources of pollution of rainwater contaminated by triazine compounds. **We recommend that further research be carried out in the UK to assess to what extent the long-range transport of other pesticides presents an environmental hazard.** (7.140) In addition, the precautionary approach suggests that more care is needed to minimise the extent of offsite pesticide drift, especially when application techniques are used which enhance the formation of spray. Recent surveys of water in public supply or abstracted for use in public supply have revealed many cases where the limits prescribed in the relevant EC directive have been exceeded. We consider that further work is needed to assess the long term environmental effects of the concentrations and the potential synergistic effects of mixtures of pesticides and their degradation products now being found in freshwaters, and that more active measures are needed to prevent pesticides from reaching both surface and groundwater. **We recommend that regulatory authorities and the water undertakers should extend and improve their monitoring programmes for pesticides in surface and groundwaters and should periodically analyse and publish the results.** (7.146)

10.49 We welcome the steps being taken to identify the risks to the aquatic environment as well as to consumers of potato products from the use of tecnazene as a fungicide and sprouting inhibitor on potatoes. We look forward to the conclusion of the Advisory Committee on Pesticides' review of the present tecnazene approval. We welcome the review of the approvals
of atrazine, simazine and isoproturon. We recommend local authorities to seek to reduce their application and to use less environmentally harmful formulations. (7.148) The persistence and harmfulness of many pesticides makes it appropriate to adopt a precautionary approach to their use. In particular, there may be value in developing the concept of best practice in the use of pesticides. This would emphasise the need to use pesticides which cause the least consequential damage to other parts of the environment. We recommend that periodic surveys of the non-agricultural uses of pesticides should be commissioned by the Government and the results published. (7.150) We recommend that research on ecotoxicology and the mechanisms governing the distribution and fate of pesticides in the environment should continue. (7.152) We recommend that manufacturers of pesticides progressively improve their recovery and treatment processes until no effluent leaves their works without having been rendered effectively inert. (7.153)

10.50 We recommend that MAFF's guidance on the disposal of pesticides by farmers be further revised. (7.154) We recommend that the Government seek ways of encouraging the use of systems for treating pesticide waste on farms. (7.155) We welcome the scheme which, for 4 months, allowed unwanted or unapproved pesticides to be transferred from farms to suitable commercial stores prior to their safe disposal. We recommend that the merits of establishing a similar scheme for non-agricultural pesticides and animal health products containing pesticides should be evaluated. (7.155) We recommend that those non-agricultural employees who apply pesticides (or supervise their application) should be required to hold a certificate of competence. (7.156)

10.51 There is scope for the Government to take a more active role in developing policies to minimise use and disseminating information on pesticides to non-agricultural users. We recommend that a national strategy (including a timetable) for reducing pesticide use should form part of the UK's water quality plan. (7.158) We are doubtful, however, of the value of a global percentage reduction target. Targets should be related to individual pesticides taking particular account of their toxicity and persistence in the environment as well as of the results of research aimed at reducing pesticide usage. We recommend that the national strategy should encourage further research and development of pesticides which are specific in their effect, degrade rapidly in the environment and do not harm parts of the environment which they are not intended to control. (7.158)

Pathogenic micro-organisms in freshwater

10.52 Further investigation of the presence and sources of the pathogens in freshwaters is an important priority, so that the risks they pose, in particular for the recreational use of freshwaters, can be more fully assessed and publicised. Surveys have shown that a high proportion of inland sites used for recreational purposes would not comply with the microbiological standards of the EC directive on the quality of bathing water. It is not possible to provide a totally risk free environment for water recreation without creating conditions that would be incompatible with other water uses and the well-being of the biota. The public needs to be aware, however, of the risks to which it might be exposed and reasonable steps must be taken to reduce risks to an acceptable level. There may be some locations where disinfection measures would be justified at least when sites are being intensively used.
10.53 We discovered little evidence that inland waters are systematically monitored for microbiological quality. Controls are not normally imposed on the microbial content of discharges to water and river quality standards do not normally refer to microbiological determinands. We recommend that appropriate microbiological standards be developed for freshwaters and that these standards be used in setting statutory water quality objectives for places in which water contact activities are reasonably common. (7.176) Research being carried out should assist the development of such standards by establishing the degree of risk for the main water contact sports and recreations. Meanwhile we recommend that the regulatory authorities, in conjunction with the owners and managers of inland waters, should identify sites used intensively or on an organised basis for bathing and other sports and recreations which involve significant contact with water. (7.176) We also recommend that the microbiological quality of these waters should be monitored, the results of the monitoring entered in public registers and the public made aware of any cases where EC standards are not achieved. Similarly, when improved standards have been developed for freshwaters, the public should be informed of any failure to achieve them. (7.176) If monitoring were to indicate persistent failure, action would be needed to relocate facilities or remedy the source of pollution.

Economic instruments

10.54 Practical decisions about pollution are influenced, explicitly or implicitly, by evaluations of costs and benefits. Pollution charging schemes should help to make possible progressive reductions in pollution over a long period and an eventual transition to conditions in which acceptable levels of pollution are both low and declining. It would, however, be unacceptable to introduce a system of market mechanisms which did not provide at least as much confidence that water quality standards would be achieved as the present system of regulation, or which could not ensure compliance with EC obligations. For point discharges into freshwater, therefore, economic instruments by themselves do not offer an acceptable approach; more traditional forms of regulation, operating with due flexibility, must remain in place. The principal role of any market mechanism should therefore be to reinforce the regulatory system to ensure that it works as cost-effectively as possible. A charging scheme would be more suited than tradable permits to fulfilling this function in the context of point discharges to freshwater.

10.55 An incentive charging scheme, introduced in addition to the existing system of discharge consents, could be designed to:

- improve cost-effectiveness;
- encourage new technology;
- act as a continuing incentive to dischargers to reduce their discharges below present regulatory limits;
- reinforce the 'polluter pays' principle;
- provide a strong message to reinforce public attitudes towards pollution;
- reinforce regulation; and
- act as a source of revenue.

These are valuable objectives which cannot be achieved by the existing system of consents alone.
10.56 We recommend that a charging scheme for point discharges to water should be adopted in the UK. (8.46) It should replace the cost-recovery schemes operating in Great Britain. It should cover all point source discharges which are subject to consent, the charge being based on the volume and content of the effluent as specified in the discharge consent. (8.47) When monitoring samples exceed consent levels, higher charges should automatically be levied. Reductions in total charges could be offered to firms to encourage them to reduce discharges significantly below their consent levels. We recommend that the level of the charge should be comparable to those in the Netherlands and Germany. (8.52) It should be set initially such that the total income generated should be roughly similar to that generated under the NRA’s cost recovery scheme, then increased in annual steps according to a published, predetermined programme to reach the desired level over a period of about 5 years. (8.53)

10.57 Other areas for charging merit consideration. They include storm overflows, surface water run-off, accidental discharges and activities that risk pollution. Some of the most serious problems of freshwater quality in the UK are the result of pollution originating from diffuse sources. We recommend that the Government encourage the EC Commission to explore the possibilities for innovative charging schemes as a means of reducing water pollution from diffuse sources. (8.50)

10.58 We recommend that the NRA, the RPAs and DOE(NI) should be responsible for the calculation and collection of charges and for paying out any grants associated with the scheme. (8.54) The revenue should be available to them not only to cover the costs of regulation but also to fund pollution prevention measures and programmes and research to improve water quality. The Government should also consider introducing a scheme to provide grants to industry for investment in pollution abatement, funded by the income from the charges. (8.55) The grants could be available to all dischargers liable for the charges. Loans for pollution abatement investment might also be offered. Grants would reinforce the incentive effect of the charges and help industry to adapt to the new financial context. We suggest that any grant scheme should not be restricted to capital projects but should also cover other activities designed to reduce pollution.

10.59 We recommend that sewage disposal should be covered by the charging and any grants schemes in the same way as other point discharges. (8.59) The Office of Water Services and the other regulators of the sewerage undertakers would need to ensure that, in paying the charges, the undertakers had a financial incentive to improve their discharges. They would also need to consider what pricing and other implications there might be for the privatised water companies in England and Wales as a result of any grants scheme for investment in pollution abatement for which they would be eligible.

10.60 Requiring polluters to pay for discharges into water without making a similar requirement for discharges to other environmental media might introduce a distortion by encouraging firms to discharge to other media rather than to water. To move towards consistent treatment we recommend that the Government should examine the scope for the introduction of market mechanisms for the disposal of pollutants to air and land. (8.60)

Inheritance from the past and legacy for the future

10.61 Freshwater quality is affected by activities which alter the flow of rivers as well as by pollution. Abstraction and discharge controls must be
exercised in an integrated fashion to ensure that the desired water quality is maintained. The option for establishing an Environment Agency in England and Wales that involved placing responsibility for water resources and responsibility for water quality in different regulatory authorities would severely inhibit the scope for integrated planning and operation of these responsibilities. It would also make much harder the development of a system of catchment management plans. We therefore consider that that option should not be pursued and we recommend that the Government ensure that future arrangements for the control of freshwater pollution in England and Wales will enable the integration of water quality and quantity regulation to be maintained and enhanced. (9.2) The NRA is identifying minimum acceptable flows in its catchment planning process and we recommend that it should develop the concept further. It should consider whether the use of statutory minimum acceptable flows might help to strengthen control over activities affecting quantity and quality. (9.3)

10.62 The NRA is considering the need to amend or revoke some abstraction licences. Some licence holders may be statutorily entitled to compensation for loss of or restrictions on their licences. The Government will need to ensure that adequate funds are made available to the NRA for any such cases. We support the view that, in considering applications for abstraction, the NRA should give weight to the desirability of preserving important natural sites as well as of furnishing public supplies. We recommend that the Government should look again at the case for licensing all water abstraction in Scotland. As in England and Wales, such controls should be exercised by the authorities responsible for regulating water quality. (9.7) We recommend that the review of abstraction licensing under way in Northern Ireland should take full account of the importance of managing water quality and quantity in an integrated fashion. (9.7)

10.63 It is impossible to separate the management of waters from that of land: the whole drainage basin—or catchment—must be considered as a unit for water management. We commend the development of catchment management plans. Aquifer protection policies could be brought together with the associated catchment plans.

10.64 Decisions which might lead to changes in land use need to take account of the likely impact on water quality. Many such changes are controlled through town and country planning legislation which enables protection of freshwaters to be taken into account in the evaluation of proposed developments. We recommend that planning authorities should ensure, through consultation with the water regulatory authorities, that their development plans take full account of the need to protect both the quantity and the quality of water resources. (9.13) The Government has issued advice to planning authorities on protection of the environment and, in particular, of groundwater. We recommend that the water regulatory authorities, for their part, should consider what kinds of land use proposal might prejudice freshwater resources and draw these to the attention of planning authorities to take into account in development plans. (9.13)

10.65 We recommend that planning authorities should be required to consult the water regulatory authorities and the water and sewerage undertakers on proposals of significant concern to them. (9.15) A planning authority which takes a decision against the advice of a statutory consultee should be required to provide, on request, a statement of its reasons for not following that advice. (9.15) This issue goes beyond the field of water pollution and our proposal should be capable of application to all planning decisions.
10.66 Procedures for assessing the likely impact on water quality of proposed land use changes have been strengthened by the introduction of an environmental assessment procedure. We recommend that the Government review the criteria and thresholds contained in its advice on whether certain projects require environmental assessment. (9.16) However, there is no size limit below which a project can be guaranteed to have no significant environmental impact. When a local planning authority considers a planning application, it may request information about the likely effects on the environment. We recommend that the Government encourage authorities to exercise this power unless they consider the environmental impact is likely to be minimal. It should issue guidance on information which would be suitable in different cases, so that the information sought is appropriate to the scale and nature of the project and its potential environmental impact. (9.17) We recommend that the Government encourage the development of suitable procedures for such assessment with a view to devising straightforward arrangements appropriate to the task. (9.17)

10.67 We recommend that the water regulatory authorities draw up lists of vulnerable watercourses which might benefit from protection by water protection zones, particularly those which are threatened by activities not susceptible to control through the land use planning system, and that the Government consider favourably applications from them for designation of protection zones. (9.18)

10.68 Although the basis for controlling discharges in the UK has been well-founded its implementation has not always been satisfactory. Much criticism has focused on discharges from sewage treatment works. We warmly welcome the high planned rates of investment designed to improve such discharges, improved compliance with consents and the active enforcement policy adopted by the NRA. Deterioration in the quality of water is not, in our view, acceptable other than as a short term expedient in exceptional circumstances. It represents an unsustainable use of the environment which, if not corrected, ultimately imposes costs which future generations have to bear. We believe that the public views an improving environment as an important priority and there appears to be a willingness to bear the associated costs.

10.69 The active enforcement policy adopted by the NRA has been widely welcomed. Enforcement must be the subject of a clear, consistent and publicly defensible policy. The regulatory authorities should ensure that serious, repeated or reckless breaches of consents will lead to prosecution. We recommend that companies put in place arrangements for ensuring that responsibility for their discharges lies with a manager at an appropriately senior level with commensurate authority who is in a position to engage in constructive dialogue with the regulators. (9.23)

10.70 A firm approach by the regulatory authorities towards breaches of consents needs to be matched by a willingness on the part of the courts to impose fines which reflect the gravity of the offences. We encourage the NRA to seek severe fines and the award of costs and damages in cases of serious pollution and to take the most serious cases to the Crown Courts. In Scotland, all criminal prosecutions are undertaken by procurators fiscal. We recommend that the Government emphasise to the legal authorities in Scotland the importance of enforcing water pollution legislation so that river purification authorities can have confidence that cases will be taken to court where relevant evidence is available. We further recommend that the Government seek means of enabling river purification authorities to recover their costs associated with the prosecution, as can the NRA. (9.25)
10.71 As pollution from point discharges is progressively reduced, further improvements in quality increasingly depend on reducing diffuse pollution. Action must be addressed to the activities which lie behind the diffuse inputs and to the location of these activities. Some pollution problems may be so severe and so deep-seated that full amelioration is very difficult to achieve. An approach to water quality founded on sustainable use would aim to prevent such cases occurring in future.

Recommendation 97

Recommendation 98

Recommendation 99

10.72 We recommend that the Government bring forward, as early as possible, proposals for regulations covering the construction of stores on non-agricultural premises in order to reduce the risk of pollution incidents from these sources. (9.28) We recommend that the water regulatory authorities be given powers, modelled on the provisions of the Health and Safety at Work Act, enabling them to inspect premises and issue improvement and prohibition notices where they identify significant water pollution risks. (9.29) Arrangements for HSE inspectors to perform these tasks on behalf of the regulatory authorities would be advantageous.

10.73 Government policy in respect of freshwater quality, as for many aspects of environmental protection, is increasingly determined by legislation negotiated in and adopted by the European Community. We recommend that the Government encourage the Community to:

- seek a high level of environmental protection, taking account of the different circumstances of member states;
- ensure that Community policies in all relevant fields take environmental considerations fully into account;
- ensure that the best available scientific understanding is fully considered in framing Community legislation;
- take greater account of the costs and benefits of legislation for the protection of the environment; and
- develop a greater degree of openness and public accountability for environmental policy. (9.33)

Recommendation 100

Recommendation 101

Recommendation 102

10.74 We recommend that, in working for a high level of environmental protection, the Government should encourage the Community to adopt policies which will allow diversity and innovation in solutions to problems to flourish. (9.35) We welcome the efforts the EC Commission is making to integrate environmental issues into other policy areas. We recommend the Government use the experience it has gained from its own initiatives to support further moves in this direction within the Community. (9.36) As the Community addresses the problem of agricultural surpluses the opportunity should be taken to introduce financial signals that will work to the benefit of the environment. We recommend that the Government encourage moves in that direction. (9.36)

Recommendation 103

10.75 Both the EC Environmental Action Programmes and the amended Treaty of Rome refer to the need to take account of available scientific and technical data in determining Community action on the environment. The legislative process would be improved and there could be more open debate of the merits of the Commission's proposals if the Commission published, with its proposals, summaries of relevant material obtained during preparatory work. We recommend that the Government encourage the Commission to
Summary and Recommendations

do so. (9.37) We recommend that, in discussing proposed new directives, the Government should seek to ensure that they always contain the necessary flexibility for review in the light of new scientific knowledge or in other relevant circumstances. (9.38) We recommend that the Government encourage the Commission to develop proposals which would secure the support of the Council of Ministers for a formal procedure to review existing directives. (9.38)

10.76 We recommend that the Government encourage the Community to develop a mechanism for reviewing the progress which has been made in achieving environmental aims. The review procedure should include meetings open to the press and to non-governmental organisations, thus enhancing the public accountability of EC environmental policy. (9.40)

10.77 There is a long-standing view is that it is acceptable and sensible to make use of the assimilative capacity of the environment. Use of the environment to dispose of wastes in this manner has to be carefully controlled. Increasingly, new attitudes towards the discharge of wastes are being developed. Many major companies, including some leading British firms, have announced their intention to cut levels of pollution substantially.

10.78 We consider that progressively less reliance should be placed on the environment as a mechanism for processing anthropogenic waste. We recommend that the water quality objectives approach should increasingly be supplemented by technology-based emission limits, tightened progressively in accordance with BATNEEC. Also, the objectives themselves should be tightened progressively, to reflect increasingly ambitious targets for water quality, and consented discharge levels be reduced accordingly. (9.44) We recommend that the Government urge the European Community to introduce a programme based on the US Toxics Release Inventory; it should apply to all significant polluting activities not only those involving manufacture. (9.45)

10.79 The activities of earlier generations provided an inheritance for this generation, an inheritance of wealth but also of environmental degradation. In the same way, the activities of today will leave a legacy, of good and ill, to future generations.
ACKNOWLEDGEMENTS

In closing we wish to express our gratitude to all those organisations and individuals, listed in appendix 2, that have assisted us during the course of this study. Their help has been invaluable. To any who may have slipped through the net we offer our apologies as well as our thanks. We also wish particularly to thank our consultant, Dr Ron Packham, who helped us in our deliberations and those organisations which prepared at our request the studies that are reproduced in appendices 5 and 6 and in the separate accompanying volume. Of these, we should particularly like to thank the Water Research centre for also assisting with the drafting of chapters 2 and 3 of this report. Finally, we have as ever been ably assisted by our Secretary, Brian Glicksman, and his staff, who have put in an enormous amount of work and to whose unflagging efforts we should like to pay tribute.

ALL OF WHICH WE HUMBLY SUBMIT FOR YOUR MAJESTY'S GRACIOUS CONSIDERATION.

Lewis (Chairman)
Cranbrook
Barbara Clayton
Henry Charnock
Henry Fell
Peter Jacques
John Lawton
Richard Macrory
J Gareth Morris
Jeremy Pope
Donald Reeve
Emma Rothschild
William Scott
Aubrey Silberston
Charles Suckling

B Glicksman  Secretary
D Aspinwall  Assistant Secretary
M Davies  Assistant Secretary
June 1992
APPENDIX 1

MEMBERS OF THE ROYAL COMMISSION AND CONSULTANT FOR THE STUDY

Chairman

*The Rt Hon The Lord Lewis of Newnham, Kt, MA, MSc, PhD, DSc, ScD, CChem, FRSC, FRS
Professor of Inorganic Chemistry, University of Cambridge
Warden of Robinson College, Cambridge

Members

Sir Geoffrey Allen, PhD, FRS
Executive Adviser to Kobe Steel Ltd
Vice President of the Royal Society
Member of the Industrial R & D Advisory Committee of the Commission of the European Communities
President, Plastics and Rubber Institute
Chairman of the Council of Scientific and Technological Institutes

Professor H Charnock, CBE, MSc, DIC, FRS
Emeritus Professor of Physical Oceanography, University of Southampton
Chairman, Meteorological Research Sub-committee, Meteorological Committee

Professor Dame Barbara Clayton, DBE, MD, PhD, HonDSc(Edin), FRCP, FRCPE, FRCPath
Honorary Research Professor in Metabolism, University of Southampton
Past-President, Royal College of Pathologists
Chairman, MRC Committee on Toxic Hazards in the Environment and the Workplace
Deputy Chairman, Department of Health Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
Chairman, Standing Committee on Postgraduate Medical Education Honorary Member, British Paediatric Association

*The Rt Hon The Earl of Cranbrook, MA, PhD, DSc, DL, FLS, FIBiol
Partner, family farming business in Suffolk
Chairman, English Nature
Chairman, Institute for European Environmental Policy (London)
Non-executive Director, Anglian Water plc
Member, Broads Authority and Harwich Haven Authority
Vice-President, National Society for Clean Air and Environmental Protection

Mr H R Fell, FRAgS, NDA, MRAC
Managing Director, H R Fell and Sons Ltd
Council Member, Royal Agricultural Society of England
Member, Minister of Agriculture's Advisory Council on Agriculture and Horticulture (1972-81)
Commissioner, Meat and Livestock Commission (1969-78)
Past-Chairman, The Tenant Farmers Association
Appendix 1

**Sir John Houghton, CBE, FRS**
Chief Executive (formerly Director-General) of the Meteorological Office 1983–1991
Chairman of the Scientific Assessment Working Group of the Intergovernmental Panel on Climate Change
Past Deputy Director of the Rutherford Appleton Laboratory, SERC
Professor of Atmospheric Physics, Oxford University 1976–83
President of the Royal Meteorological Society 1976–78
Vice-President of World Meteorological Organisation 1987–1991

**Mr P R A Jacques, CBE, BSc**
Head, TUC Social Insurance and Industrial Welfare Department
Secretary, TUC Social Insurance and Industrial Welfare Committee
Secretary, TUC Health Services Committee
Secretary, TUC Pensioners Committee
TUC Representative, Health and Safety Commission
TUC Representative, Social Security Advisory Committee

**Professor J H Lawton, BSc, PhD, FRS**
Director, Natural Environment Research Council Interdisciplinary Research Centre for Population Biology, Imperial College, Silwood Park
Professor of Community Ecology, Imperial College of Science, Technology and Medicine
Member, British Ecological Society
Member, American Society of Naturalists
Council Member, Royal Society for the Protection of Birds

**Professor R Macrory, Barrister, MA, FRSA**
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Associate Director, Imperial College, Centre for Environmental Technology
First Chairman, UK Environmental Law Association (1986–88)
Editor in Chief, Journal of Environmental Law
Formerly specialist adviser to the House of Commons Select Committee on the Environment
Specialist adviser to the House of Lords Select Committee on the European Communities
Member of the UK National Advisory Group on Eco-labelling

**Professor J G Morris, BSc, DPhil, FIBiol, FRS**
Professor of Microbiology, The University College of Wales, Aberystwyth
Chairman, SERC Biological Sciences Committee (1978–1981)
Chairman, UGC Biological Sciences Committee (1981–1986)
Member, Society for General Microbiology

**Mr J J R Pope, OBE, MA, FRSA**
Deputy Chairman and Managing Director, Eldridge, Pope and Co plc, Brewers and Wine Merchants
Deputy President, Food and Drinks Federation (1987–1990)
Member, Top Salaries Review Body

**Mr D A D Reeve, CBE, BSc, FEng, FICE, FIWEM**
Deputy Chairman and Chief Executive, Severn Trent Water Authority (1983–85)
Past-President, Institute of Water Pollution Control
Appendix I

Past-President, Institution of Civil Engineers
Member, Advisory Council on Research and Development, Department of Energy
Additional Member, Monopolies and Mergers Commission

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Research Fellow, Sloan School of Management, Massachusetts Institute of Technology (MIT)
Associate Professor of Science, Technology and Society, MIT, (1978–1988)
Member, OECD Group of Experts on Science and Technology in the New Socio-Economic Context (1976–1980)
Board Member, Stockholm Environment Institute

MR W N SCOTT, OBE, BSc, FIChemE, FInstPet, FInstD
Director, Shell International (1977–85)
Non-executive Director, Anglo and Overseas Investment Trust
Non-executive Director, Shell Pension Trust Consultant, UK and Japanese companies
Past-Chairman, CONCAWE

PROFESSOR Z A SILBERSTON, CBE, MA
Senior Research Fellow, Management School, Imperial College of Science, Technology and Medicine
Professor Emeritus of Economics, University of London
Secretary-General, Royal Economic Society
Member, Restrictive Practices Court
Past President, Confederation of European Economic Associations

*DR C W SUCKLING, CBE, PhD, DSc, DUniv, CChem, FRSC, Senior Fellow RCA, FRS
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Honorary Visiting Professor, University of Stirling

Consultant

DR R F PACKHAM, BSc, PhD, CChem, FRSC, FIWEM
Visiting Professor, Imperial College of Science, Technology and Medicine (1983–1990)
Past President, Institution of Water and Environmental Management
Consultant in environmental science

*Members whose terms of office end with the publication of this report.

Towards the end of the study Sir John Houghton and Sir Geoffrey Allen were appointed members of the Commission. Due to their other commitments they were unable to play a significant part in our deliberations and so felt that they could not properly sign this report. With completion of this report Sir John Houghton has succeeded Lord Lewis as Chairman of the Commission.
APPENDIX 2

ORGANISATIONS AND INDIVIDUALS WHO CONTRIBUTED TO THE STUDY

Listed below are those organisations and individuals who gave written evidence or assisted the Commission in other ways during the study. Those marked * gave oral evidence or a factual presentation at a meeting of the Commission. Those marked + gave oral evidence during visits, details of which are listed at the end of this appendix.

Government Departments
Department of Agriculture and Fisheries for Scotland
Department of the Environment*
Department of the Environment (Northern Ireland)
Department of Health
Ministry of Agriculture, Fisheries and Food*
Scottish Development Department +

Other Organisations
Agricultural and Food Research Council
Albright and Wilson Ltd*
Altwell Ltd
Anglian Water Services Ltd +
Association of County Councils
Association of District Councils
Binnie and Partners*
The Brewers’ Society
British Agrochemicals Association Ltd
British Coal +
British Ecological Society
British Effluent and Water Association
British Geological Survey +
British Leather Confederation
British Marine Industries Federation
British Medical Association
British Nuclear Fuels plc +
British Paper and Board Industry Federation
British Waterways
Broads Authority +
Cardiff Laboratories for Energy and Resources Ltd
Central Council of Physical Recreation
Central Electricity Generating Board
Centre for Research in Aquatic Biology, Queen Mary College, London
Clyde River Purification Board +
Commission of the European Communities*
Confederation of British Industry
Conservation Association of Botanical Societies
The Conservation Society
Conservation Trust
Convention of Scottish Local Authorities
Countryside Commission
Appendix 2

Countryside Commission for Scotland
Dorset County Council (Heritage Coast Project)
ECOVER
Eldridge Pope and Co plc+
Environmental Resources Limited*
European Chemical Industry Ecology and Toxicology Centre (ECETOC)
European Institute for Water
Federation of European Salmon and Trout Growers+
The Fellowship of Engineering
Fertiliser Manufacturers Association Ltd
Field Studies Council
Food and Drink Federation
Friends of the Earth*
Forestry Commission
Forth River Purification Board
Freshwater Biological Association+
Frome, Piddle and West Dorset Fishery Association
Game Conservancy Trust
German Federal Ministry of the Environment, Nature Protection and Reactor Safety+
Grampian Regional Council: Department of Water Services
Greenpeace UK
Hesse Environment Ministry+
Imperial Chemical Industries plc+
Institute for European Environmental Policy, Bonn+
Institute of Biology
Institute of Hydrology+
Institute of Terrestrial Ecology+
Institute of Wastes Management
The Institution of Civil Engineers
The Institution of Environmental Sciences
Institution of Water and Environmental Management
Lake District National Park Authority+
London Economics*
MAFF Pesticide Usage Survey Group
Medical Research Council
Ministry of the Environment, Planning and Land Use, North Rhine Westphalia+
National Farmers' Union+
National Farmers' Union of Scotland
National Federation of Anglers
National Rivers Authority*+
National Trust+
Natural Environment Research Council+
Nature Conservancy Council*+
Nature Conservancy Council of Scotland
Northumbrian Water Ltd*
North West Water Ltd+
Office of Water Services
Oxfordshire Health Authority
Public Health Laboratory Service*
River Piddle Protection Association
The Royal Environmental Health Institute for Scotland
Royal Society of Chemistry
The Royal Society of Health
Royal Society for Nature Conservation
Royal Society for the Protection of Birds
The Royal Town Planning Institute
The Salmon and Trout Association
Science and Engineering Research Council
Appendix 2

Scottish River Purification Boards Association+
Scottish Salmon Growers Association
Severn Trent Water Ltd+
The Soap and Detergent Industry Association
Soil Survey and Land Research Centre
The Soil Association
South Lakeland District Council+
Southern Water Authority
The Sports Council
State Agency for Water and Waste, North Rhine Westphalia+
Textile Finishers Association+
Torridge Action Group
UK Environmental Law Association
Ullswater Navigation and Transit Co Ltd+
Ulster Angling Federation Ltd
University of Stirling*+
Upwey Trout Farm and Hatchery+
Water Authorities Association
Water Companies' Association
Water Services Association
Water Research centre*+
Welsh Water Authority
Welsh Counties Committee
Wessex Water Authority+
Wynford Eagle Farm+
Yorkshire Water Authority

Individuals
Dr B Beavis, Newcastle University*
Professor G Codd, Department of Biological Sciences, University of Dundee+
Professor B Moss, Department of Biology, University of Liverpool
Dr Jean Munroe, Florence Nightingale Hospital
Mr J C V Pezzey, University of Bristol*

Visits
During the course of this study members of the Commission visited the facilities and met representatives of the organisations listed below.

4 July 1986 Water Research centre, Medmenham Laboratory

12 January 1987 Nature Conservancy Council

4–5 June 1987: Dorset
Eldridge Pope and Co plc
Upwey Trout Farm and Hatchery
Wynford Eagle Farm
Wessex Water Authority: Dorchester Sewage Works
Freshwater Biological Association: East Stoke site
An open meeting for members of the public was held in Dorchester Town Hall on 4 June 1987

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17 September 1987
Wessex Water Authority : Regional Scientific Centre, Saltford
 : Regional Control Centre, Bristol

22–24 November 1989 : Federal Republic of Germany
State Agency for Water and Waste, North Rhine Westphalia
Ministry of the Environment, Planning and Land Use, North Rhine Westphalia
Federal Ministry of the Environment, Nature Protection and Reactor Safety
Institute for European Environmental Policy, Bonn
Hesse Environment Ministry

1 March 1990
National Rivers Authority, Anglian Region

6 March 1990
Natural Environment Research Council : Institute of Hydrology
 : Institute of Terrestrial Ecology
British Geological Survey

2–5 May 1990 : Scotland
Institute of Aquaculture at Stirling University
Howietoun Fish Farm
Clyde River Purification Board
Dalquharran Colliery, Dailly, Ayrshire
Department of Biological Sciences, University of Dundee
Scottish Development Department
Scottish River Purification Boards' Association
An open meeting for members of the public was held at the Royal Society of Edinburgh on 4 May 1990

25 May 1990 : The Broads
Broads Authority
National Rivers Authority, Anglian Region
Anglian Water Services Ltd : Stalham Sewage Works

11–13 July 1990 : North West and Lake District
Natural Environment Research Council : Institute of Freshwater Ecology
Lake District National Park Authority
South Lakeland District Council
Nature Conservancy Council
National Farmers Union, North West Region
Ullswater Navigation and Transit Co Ltd
National Trust
North West Water Ltd
British Nuclear Fuels plc
National Rivers Authority, North West Region
Imperial Chemical Industries plc
Albright and Wilson Ltd
Textile Finishers Association

30 May 1991
National Rivers Authority, Severn Trent Region : Lea Marston Purification Lakes
Severn Trent Water Ltd : Coleshill Sludge Incineration Plant
APPENDIX 3

ORGANISATIONAL AND REGULATORY ARRANGEMENTS IN THE UK

This appendix describes briefly the principal regulatory bodies mentioned in the report and the differing organisational arrangements for water supply and sewage disposal throughout the United Kingdom.

In England, Government policy for water quality matters is largely the direct responsibility of the Department of the Environment (DOE) which takes advice from other Departments (such as the Ministry of Agriculture, Fisheries and Food and the Department of Health) as appropriate. DOE also normally takes the lead for the UK in the development of EC law and of international agreements on water quality. In Scotland, Wales and Northern Ireland, water policy is the responsibility of the Scottish Office Environment Department, Welsh Office and Department of the Environment for Northern Ireland respectively. There is close liaison between Government Departments on matters of common interest.

England and Wales

Until 1989, 10 regional Water Authorities (WAs) provided water and disposed of sewage, regulated discharges of effluent and licensed water abstractions in their areas. They were also responsible for some other functions, notably land drainage, in some cases in a supervisory capacity. In some areas, drinking water was (and still is) supplied by statutory water companies (some of which have now converted to plc status). Following the privatisation of the water supply and sewerage functions of the water authorities (now exercised by water services companies), the National Rivers Authority (NRA) was set up, with 10 regional units based on the former water authorities' areas, to discharge the regulatory and other functions not transferred to the private sector. It began operating on 1 September 1989 and now employs nearly 8,000 people, of whom 1,900 work on pollution control and 900 on water resources. The remainder work on flood defence (4,300), fisheries (550), navigation (150), and recreation and conservation (125).

Her Majesty's Inspectorate of Pollution is part of the Department of the Environment and was established in 1987 by merging the former Radiochemical, Industrial Air Pollution and Hazardous Waste Inspectorates. Under the Environmental Protection Act 1990 it is implementing a system of integrated pollution control which will require operators of processes scheduled because of their polluting potential to use the best available techniques not entailing excessive costs (BATNEEC) to prevent or minimise pollution. A memorandum of understanding between the NRA and HMIP governs monitoring responsibilities between the two organisations. HMIP regulates discharges to water of prescribed substances and those arising from processes scheduled under the Environmental Protection Act 1990. Hence its consent is required before a sewerage undertaker may permit 'red list' substances (see appendix 4) to be discharged into the sewerage system. HMIP also regulates the disposal of radioactive waste and oversees local authorities' performance of their waste regulation functions.

The Director General of Water Services (who is serviced by the Office of Water Services (OFWAT)) was established by the Water Act 1989 to regulate prices set, and standards of service delivered by, the water services companies and to operate new arrangements for the representation of customers. Price increases in the water industry are limited by a formula (Retail Prices Index) plus a variable (factor K). The K factors reflect what a company needs to charge in order to finance the provision of, and improvements in, services to customers. They take into account capital expenditure and operating costs, offset by productivity improvements and, where appropriate, the proceeds of land sales.
The Drinking Water Inspectorate was created in January 1990 in order to oversee drinking water quality and ensure compliance with legal requirements.

Scotland
Water supply and sewerage services are the responsibility of seven regional and three islands councils. On the Scottish mainland, catchment-based River Purification Boards (RPBs) have been responsible since the 1950s for controlling water pollution. The functions of the seven existing boards include the promotion of the cleanliness of inland and tidal waters and the conservation of water resources in their area. They have the powers to grant consent for discharges of trade and sewage effluent. They do not have responsibilities which parallel those of the NRA for land drainage, fisheries or navigation, nor is there a comprehensive water abstraction licensing regime in Scotland. The RPBs now have well over 300 staff. In the islands, pollution control duties are carried out by the three islands councils, and they and the RPBs are collectively described as River Purification Authorities (RPAs).

HM Industrial Pollution Inspectorate is charged with preventing, minimising and controlling pollution by industry and has a similar role to HMIP in England and Wales except that some scheduled processes are regulated by the RPAs.

Northern Ireland
The Department of the Environment for Northern Ireland (DOE(NI)) is responsible for both the provision of water and sewerage services in the Province (by its Water Services Division) and for the regulation of freshwater quality (by the Environment Protection Division). The Environment Protection Division’s powers are similar to those of the Scottish RPBs. It is intended that on 1 April 1993, the Water Services Division will become a wholly Government owned company and will thus move closer to the separation of regulator from undertaker now achieved in the rest of the UK.

Environment Agencies
The Government has announced its intention to set up two Environment Agencies (one for England and Wales and one for Scotland) which, if implemented, would restructure the organisational arrangements in England, Wales and Scotland.
APPENDIX 4

EC DANGEROUS SUBSTANCES LISTS AND UK RED LIST

Around one hundred thousand chemical substances are currently in use in Europe. Some of these are potentially harmful to the aquatic environment and the organisms that live in and around it. Priority lists of the most dangerous substances have been drawn up by the EC Commission and the UK Government with the intention of eliminating or reducing the discharge to water of these substances.

Substances for Priority Action

EC List I Substances

Groups of substances which must eventually be eliminated as pollutants in water are named in List I of the annex to the framework directive on dangerous substances in the aquatic environment (76/464/EEC). Discharges to surface waters, ground waters and the sea are to be controlled but exceptions were made for domestic effluents and radioactive substances, the latter being subject to separate legislation.

The groups of substances are:

1. Organohalogen compounds and substances which may form such compounds in the aquatic environment.
2. Organophosphorus compounds.
3. Organotin compounds.
4. Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment.
5. Mercury and its compounds.
6. Cadmium and its compounds.
7. Persistent mineral oils and hydrocarbons of petroleum origin.
8. Persistent synthetic substances which may float, remain in suspension or sink and which may interfere with any use of the waters.

The EC Commission identified 129 candidate List I substances on the basis of their toxicity, persistence and bioaccumulation. Substances were not included that could be shown to be biologically harmless or which were rapidly converted to harmless products. Selected substances were regulated in a series of daughter directives:

—mercury and its compounds, cadmium and its compounds, hexachlorocyclohexane (lindane), DDT, pentachlorophenol, carbon tetrachloride, hexachlorobenzene, hexachlorobutadiene, aldrin, dieldrin, endrin, isodrin, chloroform, 1,2 dichloroethane, trichloroethylene, perchloroethylene, trichlorobenzene.

The daughter directives establish limits for discharges to surface waters and the sea but not to groundwater, for which controls are contained in a separate directive. They set emission standards, quality objectives and reference methods of measurement to be used in controlling discharges. Directives covering additional substances drawn from the candidate list are planned.

Substances for Preventive Action

EC List II Substances

List II in the annex to the framework directive (76/464/EEC) identifies substances for which the aim is to reduce their potential to pollute. They are either:

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substances belonging to groups in List I but for which limit values have not yet been determined, or, substances which, although they are known to have a deleterious effect on the environment can be confined to a given area and which depend for their effects on the characteristics and location of the water into which they are discharged. The classes of these substances are:

1. Metals, metalloids and their compounds: zinc, copper, nickel, chromium, lead, selenium, arsenic, antimony, molybdenum, titanium, tin, barium, beryllium, boron, uranium, vanadium, cobalt, thallium, tellurium, silver.
2. Biocides and their derivatives not appearing in List I.
3. Substances which have a deleterious effect on the taste and/or odour of groundwater; compounds which are liable to cause the formation of such substances and render water unfit for human consumption.
4. Toxic or persistent organic compounds of silicon and substances which may cause their formation in water.
5. Inorganic compounds of phosphorus and elemental phosphorus.
7. Cyanides, fluorides.
8. Substances which have an adverse effect on the oxygen balance, particularly, ammonia, nitrates.

Member states are enjoined to reduce the levels of these substances in the aquatic environment using the Environmental Quality Objective/Environmental Quality Standards approach.

GROUNDWATER PROTECTION—EC LISTS I AND II

Substances Discharged to Groundwater

Measures for the protection of groundwater were outlined in a single directive (80/68/EEC) rather than in a family of daughter directives. The approach taken to listing individual substances discharged to groundwater is fundamentally different compared to discharges to surface water. Any substance covered by the groups in List I of directive 76/464/EEC is included in groundwater List I for priority action to prevent entry to groundwater. Only substances that can be specifically shown to have limited impact through low toxicity, brief persistence etc are reclassified with List II status. For these less damaging substances action is taken to limit their entry to groundwater. The groundwater List I and List II substances are similar to those named in the framework directive (76/464 EEC) but with some minor differences. Exceptions are made when substances are discharged to aquifers which are unsuitable for other uses or are recharged for industrial or geothermal purposes.

List I

1. Organohalogen compounds and substances which may form such compounds in the environment.
2. Organophosphorus compounds.
3. Organotin compounds.
4. Substances which possess carcinogenic, mutagenic or teratogenic properties.
5. Mercury and its compounds.
6. Cadmium and its compounds.
Appendix 4

List II

1. Metals, metalloids and their compounds: zinc, copper, nickel, chromium, lead, selenium, arsenic, antimony, molybdenum, titanium, tin, barium, beryllium, boron, uranium, vanadium, cobalt, thallium, tellurium, silver.

2. Biocides and their derivatives not appearing in List I.

3. Substances which have a deleterious effect on the taste and/or odour of groundwater; compounds which are liable to cause the formation of such substances and render water unfit for human consumption.

4. Toxic or persistent organic compounds of silicon and substances which may cause their formation in water.

5. Inorganic compounds of phosphorus and elemental phosphorus.

6. Fluorides.

7. Ammonia and nitrites.

A national scheme for classification of listed substances based on clear and uniform criteria is to be drawn up by the NRA.

THE UK RED LIST

The UK Government at the 2nd North Sea Conference agreed to reduce by 50% inputs of particularly toxic substances to the sea between 1985 and 1995. These substances formed the “Red List” and were initially selected from the list of 129 candidate EC List I substances. The Red List selection procedure is based upon a number of criteria derived from the substances' toxicity, persistence, bioaccumulation potential, production levels and physical and chemical properties. It also takes into account whether the inputs are diffuse or from a point source.

The procedure uses three broad scenarios—acute toxicity, chronic toxicity or accumulation through the food chain—to assess the likely impact of the substance on the aquatic environment. For each scenario a decision tree combines the properties and the level of input to water of a substance to assess whether there is a low, moderate or high risk of pollution. The procedure requires a minimum of information to select a substance as a candidate for priority action. Owing to a lack of data on the very long term effects of carcinogenic, mutagenic or teratogenic substances no members of this category have been included in the Red List. A steering group has been set up by the NRA, however, to identify substances that are carcinogenic in the aquatic environment.

The Red List currently contains 23 substances:

Additional substances will be added to the Red List as more candidates are reviewed in the selection procedure. The UK Red List includes all of the EC List I substances controlled by daughter directives including carbon tetrachloride which, however, does not emerge as a priority substance from the UK scheme.
APPENDIX 5

THE RIVER TAME AND THE BEDFORD OUSE — COMPARATIVE CASE STUDIES

Report No.: CO 2900/1
December 1991
Author: S C Warren
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Contract No: 8157

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Annex — River quality classification

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The author wishes to express his gratitude to staff of the Headquarters and the Anglian and Severn Trent Regions of the National Rivers Authority, the Anglian Water Services Limited and Severn Trent Water Limited, and to numerous colleagues within WRC who provided valuable unpublished information and gave much helpful advice.
Appendix 5

Summary

The main features of the rivers are as follows:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Tame</th>
<th>Bedford Ouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>60</td>
<td>108</td>
</tr>
<tr>
<td>Catchment area (km²)</td>
<td>1,500</td>
<td>3,000</td>
</tr>
<tr>
<td>Impermeable area (%)</td>
<td>&gt;20</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Character</td>
<td>urban/industrial</td>
<td>mainly rural</td>
</tr>
<tr>
<td>Population (m)</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Rainfall</td>
<td>average to high</td>
<td>low</td>
</tr>
<tr>
<td>Typical flow (Ml/d)</td>
<td>1,600</td>
<td>1,600</td>
</tr>
<tr>
<td>Groundwater (%)</td>
<td>&lt;10</td>
<td>&gt;30</td>
</tr>
<tr>
<td>Effluent (%)</td>
<td>&lt;35</td>
<td>17</td>
</tr>
<tr>
<td>Used for supply (%)</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

Approximately one-third of the flow of the Tame is water imported from the Severn catchment to supply Birmingham and discharged to the Tame in the form of sewage effluent.

In the 18th century both catchments were predominantly rural and both rivers were used as a source of drinking water. In the 19th century the growth and industrialisation of Wolverhampton and Birmingham resulted in a gradual increase in pollution of the upper Tame to the point at which it could no longer be used for supply. In the absence of a strong institution responsible for pollution prevention river quality continued to deteriorate until the middle of this century as continued growth and industrialisation outstripped the capacity of the old sewerage systems. The Bedford Ouse catchment was little affected by the industrial revolution but in the second half of this century it began to be affected by the post-war intensification of agriculture and by a growth in population, both of which threatened water quality.

The establishment first of the Ouse River Authority in 1963 and then of the Anglian Water Authority in 1974 provided, however, institutional structures with the power to enforce the measures needed to protect the river. These measures were relatively easy to incorporate in new developments, such as the new town of Milton Keynes, and their cost represented a relatively small addition to the large cost of new urban development. In the Tame catchment the Trent River Authority, and later the Severn Trent Water Authority, were faced, in contrast, with the task of rehabilitating an already severely polluted river and a fragmented and overloaded sewerage system without the benefit of large development budgets in which the costs could be absorbed.

Probably more than £500 million has been spent so far on the Birmingham sewerage system but intractable problems of pollution from storm water, from unlicensed discharges and from old contaminated land limits the quality which can be achieved in the upper Tame. Nevertheless, the construction of reclamation lakes downstream of Birmingham at Lea Marston has proved very effective in protecting the lower Tame, and thus the Trent, from the consequences of episodes of pollution in the upper Tame.

The Ouse is class 2 but contamination with nitrate, largely of agricultural origin, obliges the Anglian Water Services company sometimes to blend supplies to keep within the drinking water standard. Additional treatment of the water may be needed in future to deal with contamination with pesticides. High levels of phosphate, mainly from sewage, allow algae to proliferate in the reservoirs at Foxcote and Graftham which are filled from the Bedford Ouse. Both are now treated with iron sulphate to precipitate phosphate but the water from Foxcote still suffers from problems of taste and odour after treatment.

Further improvements in the quality of the Tame are possible but will be difficult and slow to achieve. Significant improvements in the Bedford Ouse will also be difficult in view of increasing demands for supply from a river with an already high degree of re-use. Nevertheless, pollution from pesticides and nitrate is likely to decline slowly as a result of constraints on their use in agriculture.
Introduction

1. Rivers differ in the nature of the catchment which they drain, their gradient, the type of sediment, the degree of regulation to which they are subject, the extent and type of polluting inputs which they receive, the amounts of water abstracted for different purposes and the other uses to which the water is put, including its amenity value. In general inputs from point sources, such as sewage works and factories, are amenable to control but diffuse inputs, such as run-off from urban or agricultural land, and flow from groundwater can exert a considerable effect on water quality and are much more difficult to control.

2. Water quality is also affected by transient events such as heavy rainfall, which increases the flow in the river, may disturb sediments and can wash polluting material from the surface of the catchment directly into the river. It can also cause sewer overflows to discharge raw or partially-treated sewage into the river. Rivers vary in their response to heavy rain depending on the permeability of the catchments. Drought causes river flow to diminish, reducing its capacity to dilute, attenuate and assimilate polluting material. This problem can be exacerbated if greater demand for water during the drought causes abstraction to increase. Where groundwater contributes significantly to river flow increased abstraction from groundwater in the catchment can adversely affect flow.

3. Two rivers, the Tame in the Severn Trent region and the Bedford Ouse in the Anglian region, have been chosen as the subjects of a case study to illustrate the extent to which river quality is affected by pollution, the interaction between polluting inputs and the uses of the river, the management strategies which have been adopted by the responsible authorities and their effectiveness.

The Tame

4. The Tame catchment

The catchment is shown in Figure 1. The Tame rises from the Bunter Sandstone as two springs in the areas of Oldbury and Wolverhampton (Harkness, 1982) which combine with a third, Ford Brook, to form the main river with a natural flow of 30 Ml/day. The discharge of effluents derived from imported waters increases the dry weather flow to 156 Ml/day. The river runs through Wolverhampton and the city of Birmingham for a distance of approximately 26 km and is joined by the Rivers Blythe and Cole at Coleshill 4 km further on. After 13 km it is joined by the River Anker and flows on for 17 km until it reaches the Trent. Its total length is 60 km and the area of the catchment is 1,500 sq km (Skerry and Green, 1986). From the point of view of flow and water quality the most significant part of the catchment is that of the headwaters from source to below Lea Marston. From there until the river reaches the Trent there are no features of particular or unusual significance and it is the upper part of the river which largely determines the effect of the Tame on the Trent. This review therefore concentrates on the upper part of the catchment.

5. Historical development and general overview

In the early 1800s a scheme was commissioned to abstract water from the river to supply Birmingham, whose population was then 345,000, and to replace supplies previously obtained from boreholes. Industrial development in the 19th century took place away from the river but the industrial activities, which included coal gasification and metal working, and the associated transport and waste infrastructure began to cause pollution of the river by wastewaters and urban run-off and in 1872 abstraction was prohibited. Alternative supplies were obtained from smaller clean rivers to meet the 90 Ml/day demand. After 1904, when Birmingham began to draw supplies from central Wales, an increasing proportion of water for Birmingham was derived from the Severn catchment, outside the Tame and Trent catchments. In 1982 these imports had grown to 500 Ml/day with additional imports to the lower parts of the Tame catchment (Harkness, 1982). The Blythe and the Bourne, two tributaries of the Tame which skirt Birmingham, have remained relatively unpolluted and a total of 30 Ml/day is abstracted from them to supply Nuneaton.
Figure 1 The Tame Basin
6. The populations of the major conurbations in the Tame catchment are shown in Table 1, which was prepared from data supplied by the Office of Population Censuses and Surveys (OPCS).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Populations of major towns in the Tame catchment</th>
<th>Population in year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birmingham</td>
<td>1,014,700</td>
<td>1,020,700</td>
</tr>
<tr>
<td>Wolverhampton</td>
<td>269,500</td>
<td></td>
</tr>
<tr>
<td>Walsall</td>
<td>182,500</td>
<td></td>
</tr>
<tr>
<td>Tamworth</td>
<td>47,000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,513,700</td>
<td>1,584,500</td>
</tr>
</tbody>
</table>

The decline in the populations of Birmingham and Wolverhampton appear to have been more than offset by rises in the populations of Walsall and Tamworth. These rises are so large over a seven-year period that, before any conclusions are drawn, it would be desirable to confirm that they are not the result of arbitrary extraneous factors such as changes in the definition of boundaries.

7. The imported water, which is of a different origin from the natural flow, is treated after use and the effluent discharged to the Tame, whose flow is thus very considerably augmented. In 1982 the flow of the Tame where it joins the Trent was 1,600 Ml/day compared with the 1,100 Ml/day of the Trent itself. In summer, when river flow is at its lowest, as much as 80% or more of the flow of the Tame may derive from sewage effluents (Hellawell and Green, 1986) and of the average flow some 56% is sewage effluent (Clayfield and Holloway, 1976). Since then more upstream sewage works have closed and at present the natural dry weather flow (dwf) of the Tame at Water Orton, just upstream of Minworth, would be 78 Ml/day and the actual dwf is 156 Ml/day.

8. One of the largest conurbations of the UK is thus situated at the headwaters of what would otherwise be a relatively small river. An estimated 20% of the area of the catchment is impermeable (Hellawell and Green, 1986) and a much greater proportion of the headwater catchment. Run-off from this area is rapid and carries a high polluting load of lead, iron, oil and particulate matter, dog excreta, food wastes and litter from road surfaces and paved areas. The catchment includes sections of the M6 and M38 and the M6/M38 interchange, run-off from which carries a very heavy polluting load. Urea is used for de-icing purposes at this interchange following the discovery of extensive corrosion of the concrete and reinforcement as a result of the use of salt for this purpose in earlier years. Urea contains nitrogen which adds appreciably to the nitrogen load of the river. Peaks of ammonia derived from the hydrolysis of urea can be detected many kilometres downstream of the interchange after rainfall. Of the urban area 40% is served by a combined sewer system, 15% by a partially separated system and the most modern 45% by separate systems for foul and surface water drainage. In practice, however, although the overflow arrangements may be different, both waste streams are eventually combined and travel down the trunk sewer to the sewage treatment works.

9. Some of the surface drainage waters discharge directly into the river and the particulate matter, including metals, accumulates in the sediments and inhibits the growth of flora and fauna even when high flows temporarily improve water quality. A number of inadequate and badly-maintained sewage works along the river between Wolverhampton and Minworth used to discharge very poor quality effluent to the river which added to its polluting load. Between 1964 and 1974 £130 million was spent on refurbishing the Minworth and Coleshill water reclamation plants and on main sewerage to transfer to Minworth the sewage which fed the inadequate works at Saltley, Tyburn, Ashold and Yardley. Subsequently, remedial work was carried out on a number of grossly inadequate works in the upper part of the catchment. As a result average
dissolved oxygen levels in the Tame rose steadily from 2–3 mg/l in 1964 to nearly 6 mg/l in 1974 and to nearly 8 mg/l by 1978. In the same period ammoniacal nitrogen levels fell from around 16 mg/l in 1964 to 6–9 mg/l in 1974 and 2–8 mg/l in 1978, depending on the sampling point (Skerry and Green, 1986; Martin, 1986). Nevertheless, the Tame was still in class 4 under the NWC classification scheme (see Annex) although its appearance was greatly improved and it could support a coarse fishery in its lower reaches. A contributory factor to this improvement was the closure of the gas works, whose effluent had been discharged to sewer. This immediately resulted in a 25% reduction in ammoniacal nitrogen levels in Minworth effluent (Harkness, 1982).

10. River pollution is particularly severe after heavy rain following a dry spell when the first flush washes the accumulated material off the paved area. The effects of heavy rain are exacerbated because the turbulence causes the re-suspension of sediments with a high biochemical oxygen demand (BOD) which depletes oxygen levels. Summer storms often occur in the evening, when photosynthesis by aquatic plants has ceased and there is little oxygen production within the river. Diffusion of oxygen from the surface is too slow to maintain oxygen levels and the river may suffer from oxygen depletion for several hours (Hellawell and Green, 1986). These episodes threaten the coarse fisheries which have become precariously established in the lower reaches of the Tame. Previously during storms water quality in the river at Minworth was usually considerably worse than the Minworth Water Reclamation Works’ effluent which was discharged into it (Lester et al., 1971). This was still the case on occasions in 1984 but the difference was less dramatic (Table 2).

11. Severe pollution events in the Tame could also pose a threat to the important coarse fisheries of the Trent downstream of its confluence with the Tame. Its impact on the Trent in 1969 and 1977/78 is shown in Table 3.

12. Forecasts made in the 1960s of demand for water in the area led to the establishment of a large Trent Research Programme (Water Resources Board, 1973) and to the development of the Trent Economic Model with a view to considering how the large expected demand could be met. In the final report on the Trent economic model the Water Resources Board considered the possibility of using the Trent for supply but, although the river could have been treated economically to WHO drinking water standard, doubts about the definition of wholesomeness led to the conclusion that it would not be acceptable and that future supplies should be taken from the Dove and Derwent catchments (Woodward, 1978). This led to an agreement to construct the Carsington dam in Derbyshire. In practice the forecasts of water demand (2,220 MI/day) by 1981 and 3,690 MI/day by 2001 were based on what proved to be unrealistic estimates of population growth, per capita consumption, industrial use and inflation (Figure 2) and were revised in 1978 to 1,670 MI/day by 1981 and 2,250 MI/day by 2001. The droughts in recent years have led to a greater emphasis being placed on flexibility in sources of supply. Since then, however, some Trent waters much further downstream are transferred to the Witham and thence to the Ancholm, whose waters are abstracted for public supply in the Anglian region.

### Table 2

<table>
<thead>
<tr>
<th>Date</th>
<th>Determinand (mg/l)</th>
<th>River Tame at Water Orton</th>
<th>Minworth Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1984</td>
<td>BOD</td>
<td>10.6</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Suspended solids</td>
<td>75</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Ammoniacal N</td>
<td>2.7</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Oxidised N</td>
<td>9.3</td>
<td>17.3</td>
</tr>
<tr>
<td>September 1984</td>
<td>BOD</td>
<td>9.1</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Suspended solids</td>
<td>62</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Ammoniacal N</td>
<td>1.9</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Oxidised N</td>
<td>6.6</td>
<td>16.4</td>
</tr>
</tbody>
</table>
### Table 3
The quality of the Rivers Trent and Tame upstream and downstream of their confluence (adapted from Woodward, 1978)

<table>
<thead>
<tr>
<th>Determinand (mg/l)</th>
<th>Trent at Yoxall (just above confluence)</th>
<th>Tame at Lea Marston</th>
<th>Trent at Nottingham</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>1969 (averages)</td>
<td>1977/78 (averages)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1969 (averages)</td>
<td>1977/78 (averages)</td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>5.7</td>
<td>4.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.6</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>8.3</td>
<td>10.7</td>
<td>9.3</td>
</tr>
<tr>
<td>Temperature (deg. C)</td>
<td>11</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Chloride</td>
<td>167</td>
<td>141</td>
<td>90</td>
</tr>
<tr>
<td>Dissolved copper</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Dissolved nickel</td>
<td>undetected</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Dissolved zinc</td>
<td>0.1</td>
<td>0.28</td>
<td>0.12</td>
</tr>
</tbody>
</table>

**Figure 2** Birmingham supply area — average daily water consumption (from Box, 1984)
Appendix 5

13. Recent developments
In the late 1970s the quality of the River Tame was still a cause for concern and a strategy comprising three elements was developed for further improving its condition and alleviating flood risks (Skerry and Green, 1986). The strategy had four main objectives:

(i) to improve the quality of the Tame to class 3 above Lea Marston and class 2 below;
(ii) to limit flooding effects in the basin up to a flood return period of 50 years;
(iii) to effect revenue savings in sewage sludge treatment and conveyance at the earliest opportunity;
(iv) to achieve these objectives at minimum capital cost.

A. The Tame Basin Reclamation Scheme
A trunk sewer scheme was to be constructed within the Tame valley to permit the closure of 12 inadequate works within the Black Country. The sewage would be conveyed to Minworth, which had been refurbished to accommodate demand forecasts which proved to be greatly exaggerated and thus had spare capacity. Two works at Anson Road and Ray Hall were to be retained but the sludge from these works was to be conveyed through the main sewer to Minworth and Coleshill for treatment and disposal (Figure 3). Overflows to the river from the sewer when it was carrying a high proportion of this sludge would have to be prevented by giving at least a five-hour warning of impending rainfall likely to cause storm overflows to operate.

B. The River Tame land drainage, flood alleviation and purification lakes scheme
A scheme to enlarge the river system following severe flooding in 1969 was revised in favour of a less environmentally damaging and more economic plan to construct a series of storage lakes. The opportunity was to be taken to construct three purification lakes which would both protect the flood storage areas from the worst effects of flood waters and provide a measure of purification of the water and allow the attainment of the mid-point of class 3.

C. The Lea Marston Lake scheme (the Tame Reclamation Lakes)
It was originally planned to construct a series of seven reclamation lakes to improve the quality of the upper reaches of the Tame with consequent benefit to the Trent, even though the Trent was not to be used as a source of water for public supply. It was decided to construct the first lake at Lea Marston, some 6 km downstream of Coleshill and 10 km downstream of the Minworth water reclamation works, where gravel extraction had provided an ideal location. A decision on the remaining lakes was deferred pending information on the performance of the first lake, which was completed in 1983 at a cost of £7 million, including ancillary works.

14. The Tame Reclamation Scheme has been implemented and the excess capacity of the Saltley–Minworth trunk sewer (Figure 3) has been used to avoid the high cost of building an entire new sewer by taking sewage from the northern works to Perry Hall. Given the environmental objectives in the 1980s, the strategy adopted for meeting them necessarily took account of practical, operational and economic factors (Halliday, 1986; Box, 1984).

15. The sewerage system in the upper Tame includes large lengths of a system dating back to the last century together with additions and modifications made over a period of many years, to which sections of new trunk sewers have been added in recent years. An impression of the complexity of the system and the way in which it overlays the river system can be gained from Figure 4. In addition to the rivers there are canals with a total length similar to the river system and these are connected to the river through overflows. The canals also receive discharges and pollutants pass between the rivers and the canal system. In order to achieve results quickly the new trunk sewer was started at the northern end to take sewage from the smaller upstream works. Ray Hall and Anson Road water reclamation works continued to operate, taking a fixed flow of sewage from the trunk sewer and returning their sludge to the sewer to be dealt with at Minworth. In this way the treatment works could operate efficiently without savage fluctuations in load and the volume of flow in the trunk sewer was reduced since the sludge constitutes only a very small
Figure 3  Trunk sewerage system (Skerry and Green, 1986)
Figure 4  Schematic representation of water reclamation works within the Tame catchment (1989)
fraction of the volume of raw sewage. The increase in solids caused by the sludge is not important since it is very small in relation to the quantity of material entering Minworth. The benefits of this were achieved more quickly by connecting the new sewer to the old one at Perry Hall rather than building another long section of sewer, since the difficulties and the social and economic costs of constructing new sewers in such an intensely built-up area are very considerable.

16. The capacity of the old sewer from Perry Hall, while it was adequate for normal flows, could not accommodate the high flows which occurred after very heavy rainfall. Furthermore, the pre-existing sewerage network is still fully connected. As a result during and after rainfall sewage backs up this point, overflows operate, manhole covers lift and localised flooding with raw sewage occurs over a small area of a playing field. The lack of adequate capacity in the old sewer is one factor which has delayed closure of the sewage works at Roway Lane in Oldbury. A number of tanks have been built to hold storm waters and consideration is being given to the construction of a new trunk sewer to eliminate the bottleneck and connect the Black Country trunk sewer with the Minworth sewers and alleviate the capacity problems but, unless and until it is completed, storm overflows will continue to limit the water quality which can be achieved.

17. In 1976 the estimated cost of the scheme to serve a 1.83 million population was £31.3 million and the cost of the scheme inherited by the new Water Authority to treat higher flows was £70 million. Of this £10 million was deleted by modifying the proposals for Minworth extensions and it was estimated that a further £14 million might be saved by using a computer control system to maximise the capacity of the existing sewerage system and avoid the need for the construction of a supplementary sewer (Box, 1984).

18. A secondary consequence of the closure of old sewage works is a decline in the flow of the Tame upstream of Minworth as more water is intercepted and conveyed to Minworth by sewer. The dwf is now only twice the natural flow and, although the higher flows of the past were derived from imported water, they have become established over a century and the customary appearance of the river will suffer if upstream flows decline anymore. In addition reduced flow provides less diluting capacity for the polluted storm waters which still discharge into the river. The eventual closure of the Oldbury sewage works at Roway Lane will result in a further important loss of flow to the river.

19. The present position
The creation of the NRA in 1989 separated the responsibility for setting environmental objectives from the operations involved in meeting them. The NRA has now confirmed the quality objectives originally set by the then Severn Trent Water Authority for the river system from the junction of the two source streams to Lea Marston of class 3, as opposed to the present class 4 and between Lea Marston and the Trent of class 2 compared with the present class 3. The upper Tame already supports fish, but fish kills during storm events occur regularly and inevitably attract unfavourable comment. The downstream section of the Tame is already very close to achieving class 2 in practice although a number of outstanding problems remain to be solved. The Trent is now class 2.

20. Capacity of the sewerage system — storm overflows
The problem of inadequate sewage works is now largely solved but the sewerage system still has inadequate capacity and storm overflows continue to cause episodes of very poor water quality. Most storm overflows have been located but there are almost certainly some discharging into the culverted sections of the river system which have not. On occasions blockages occur in the sewers which cause storm overflows to operate even in dry weather. Now that gross pollution has been dealt with a water quality model developed by STWS plc is used to determine the most cost-effective strategy for the drainage systems in future (Martin and Green, 1986).

21. Industrial discharges
Discharges of industrial waste have declined considerably as a result of the closure of the old gas works, small firms going out of business during the two recessions in the last 10 years and
improvements in effluent treatment. In addition the implementation of legislation on trade
effluents has resulted in the progressive elimination of direct trade discharges to river as they are
transferred to the sewer system. Nevertheless, as the gross problems have been solved the
remaining industrial effluents from chemical and metal factories become more important sources
of pollution. There are some illegal discharges to storm drains and to sewers and there are
discharges to the extensive culverted sections of the river which are difficult to find and monitor,
particularly when they are intermittent. The river is the responsibility of the NRA and both storm
drains and sewers are the property of Severn Trent Water Services plc but the manpower and
resources required to identify and stop every illegal discharge would be very large indeed. The
cost and effectiveness of pollution control in future is likely to depend as much on the availability
of manpower as on the availability of capital.

22. Contaminated land and waste disposal sites
Land contaminated from past industrial activities is another source of pollution. For example,
the NRA now has its own “Confined Spaces Team” and in their first investigation, to find the
source of an oil slick coming from a culvert on Bilston Brook, it was found that the oil did not
come from a pipe discharge but was seeping through the brickwork along a length of over 100 m.
The land on that side contains six rows of houses, none of which can be the source. The most
likely explanation is that the oil comes from land contaminated when the site was occupied by a
steel works now long closed since the oil contains other contaminants. Even if the source could be
proved it would be difficult or impossible to find a polluter to prosecute and from whom the costs
of preventing the discharge can be claimed. It is extremely difficult to deal with polluting
discharges of this kind and the costs are very large indeed. This type of problem is exacerbated by
rising levels of groundwater which lift organic and metallic contaminants as the water levels rise.
This has occurred on land previously occupied by a copper working factory. Another company
took over the factory but acquired only part of the land and excluded (unwittingly) the problem
area. A surface stream a short distance away is now being contaminated with nickel and copper,
as well as iron, whose origin is difficult to establish with certainty. It is thus difficult to find a
polluter to charge with the remedial costs. The leachate from waste tips also contributes to the
metal load of the river system and threatens to compromise the achievement of the reductions in
metal inputs to the North Sea agreed at the last North Sea Conference. Two tips, Slacky Lane and
Bentley Mill Lane in Walsall, alone discharge together 14.9 tonnes of nickel, 6.1 tonnes of copper
and 2.6 tonnes of zinc each year. This represents 18%, 17% and 2% respectively of the total load
of these metals carried by the river at its confluence with the Trent.

23. The Tame Reclamation Lakes
The purification lake at Lea Marston is described by Hellawell and Green (1986) and by
Woodward (1983) and is shown in Figure 5. Its total area is 25 ha and the average depth is 2.5 m,
giving a retention time of almost one day at dry weather flows, but of only 2–3 hours during flood
discharges. The water enters the lake through two concrete channels incorporating a floating
debri barrier and an oil boom. On leaving the lake the water flows over low weirs which provide
some aeration. While the lake might be expected to bring about some reduction in BOD and
ammonia its primary effect is to remove grit and suspended solids.

24. It was calculated that the lake could in theory remove 18,000 tonnes/year (49 tonnes/day) of
suspended solids. In a series of dry periods totalling 70 days suspended solids fell from 23.4 mg/l
at the inlet to 17.5 mg/l at the outlet, a removal of about 5.5 tonnes/day (Woods, 1984). During a
38 day dry spell in 1984, when flows were below 700 MI/day, suspended solids fell from 21 mg/l to
11 mg/l, equivalent to a removal of 5.9 tonnes/day (Hellawell and Green, 1986). On 31 days when
flows exceeded 2,000 MI/day average removal was 81.6 tonnes/day. The lake seemed to reduce
soluble BOD by about 25% in dry weather but achieves negligible reduction during high flows or
in winter. Total BOD is, however, reduced substantially since much of the organic matter giving
rise to BOD is associated with the sediments. During very severe storms in summer, perhaps once
every year or two, the lake did not provide sufficient protection for the river downstream
(Hellawell and Green, 1986). The River Tame was at that time able to support a coarse fishery
below the lake but its quality was governed by its exposure to episodes of pollution during storms

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Figure 5  Completed Lea Marston lake and position in proposed arrangement of lakes (Hellawell and Green, 1986)
which overwhelmed the purification capacity of the lake. Nevertheless, the greater part of the solids removed by the lake were removed during spates and the river downstream clearly benefited from this.

25. In 1987 a second purification lake was brought into use at the conclusion of another phase of gravel extraction and in 1989 the operation of both purification lakes was taken over by the NRA. The cost of operation is currently around £1.1 million, of which more than £700,000 per year is the cost of the continuous removal of silt which is partially dewatered and taken to Coleshill for further drying and disposal at another site. There have been further improvements in the quality of water downstream of the lakes and there are no plans to construct any more of the seven lakes originally envisaged.

26. The lake system was conceived as a cost-effective remedy to the intractable problem of storm water carrying heavy loads of sediment and which could be implemented within a period much less than it would take to eliminate the very large number of storm discharges responsible for the problem. The first lake is now very effective and plays a major part in the improvement of the quality of the river downstream. It has been largely responsible for the improvement of the 17 km of the lower Tame up to the confluence with the Trent and the improvement to the River Trent extends for 22.5 km to Burton. A total of 40 km of river have thus benefited from the operation of the lake. The quality of the second lake is such that it can safely be used for recreation and has an important amenity role. Nevertheless, the lake system is no more than an expedient and the NRA now carries the cost of treating an entire river in order to reduce the effects of pollutants introduced upstream. It is important that remedial works upstream continue so that the amount of sediment carried by the Tame can be further reduced. This will progressively reduce the amount of sediment trapped in the lake and thus the costs to the NRA of removing and disposing of it.

The Bedford Ouse

27. The Catchment

The Great Ouse basin is one of the largest catchments in England. It is divided for convenience into four sections, the Bedford Ouse (Figure 6), which includes the headwaters from the source to Earith and has an area of 3,030 sq km, the Ely Ouse, with an area of 3,285 sq km, the Middle Level, with an area of 815 sq km and the Tidal Ouse whose area, including the North Norfolk rivers, is 1,455 sq km. The Great Ouse rises at Teatworth near Brackley to the west of Buckingham, and is joined by Padbury Brook at Foxcote, just east of Buckingham, the River Ivel at Cosgrove, the River Ouzel at Newport Pagnell and the River Ivel between Bedford and St Neots (The Bedford Ouse Study, 1977). The Bedford Ouse is fed throughout its length by smaller rivers from the north and south. Most of these rise in impermeable clay covered catchments and their flow is dominated by surface water run-off which responds rapidly to rainfall but groundwater from the Chalk, the Greensand and Great Oolite aquifers also contributes to the base flow of the river. The total length of all rivers in the Bedford Ouse catchment is 775 km and the length of the Bedford Ouse itself is 108 km. The population of the Bedford Ouse catchment is about one million which is approaching two-thirds of the population of the whole catchment. The Bedford Ouse catchment therefore has about two-thirds of the population in just over one-third of the area of the whole catchment.

28. Towns are situated on the headwaters of most of the tributaries of the Bedford Ouse and several of these towns have been, and still are, growing rapidly in comparison with most other parts of the country as can be seen from the examples shown in Table 4, which was prepared from data obtained from the OPCS and from District Councils.

29. The Ouse catchment has overall the lowest rainfall of any part of the United Kingdom. The headwaters are in rolling countryside but then the terrain becomes flat and low-lying and the river is sluggish and meandering. Much of the rainfall falls on permeable chalk and recharges aquifers rather than running off the surface. The chalk groundwater contributes to the flow of the river system (Figure 7) and provides some 50% of the flow at Bedford. As a result seasonal variations in
Figure 6  The Bedford Ouse Area
Figure 7  Relative proportions of groundwater and surface water flows to total flow of Bedford Ouse, at four selected sites
## Table 4
Population of some towns in the Bedford Ouse catchment

<table>
<thead>
<tr>
<th>Town</th>
<th>Population in year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milton Keynes</td>
<td>100,000</td>
</tr>
<tr>
<td>Bedford</td>
<td>73,000</td>
</tr>
<tr>
<td>Biggleswade</td>
<td></td>
</tr>
<tr>
<td>Buckingham</td>
<td>5,076</td>
</tr>
</tbody>
</table>

(1990)

## Figure 8
Mean flow of Bedford Ouse at Earith (1971–1986)

<table>
<thead>
<tr>
<th>Year</th>
<th>ML/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
</tr>
</tbody>
</table>

223
Figure 9  Relative proportion of sewage effluent of total river flow at Earith (1971–1986)

flow are less than in rivers receiving a greater part of their flow from run-off. The smaller difference between maximum and minimum flows makes the Bedford Ouse a reliable source of water throughout the year. The large contribution of groundwater to flow means that abstractions from the river cannot be considered in isolation from groundwater abstraction and flows are reduced during drought when the groundwater table falls. The Bedford Ouse is probably better thought of less as a stream of water in an isolated channel than as only the visible part of a much larger body of water moving not only through the river channel but also through the adjacent gravels. At times of high flows the water in the channel moves more rapidly than the mass of water in the gravel beds and water and pollutants exchange relatively slowly between them. At times of low flows there is time for much more extensive inflows and outflows and these provide the
Surface Water Abstractions (1970–86)

Groundwater Abstractions (1970–86)

Figure 10  Mean daily volumes, by use, of water abstracted from the Bedford Ouse (1976–1986)
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system with a much greater assimilative capacity than a river the apparent size of the Bedford
Ouse would have alone. The flows in the river over the past 20 years are shown in Figure 8.

30. Historical developments and general overview

The waters of the catchment are extensively used for public supply and for irrigation. The water
used for public supply is largely returned to the river as sewage effluent, which constitutes an
important part of the flow of the river (Figure 9). The returned effluents have the effect of
evening out the flow of the river, mitigating the low flows which occur during droughts and
increasing the yield of reservoirs. Up to one-third of public supply is derived from groundwater
which is thus directly transferred to the river through the sewage system after it has been used. Of
the water used for spray irrigation, some is lost by evaporation, some is lost by evapotranspiration
from the plants which use the water and the remainder recharges the aquifer by infiltration.

31. At several points water is abstracted from the river for public supply and there are storage
reservoirs at Foxcote just west of Buckingham, commissioned in 1956, and at Grafham Water
downstream of Bedford, commissioned in 1966, into which water is pumped from the river.
Grafham is about 7 km from the river and the intake for this reservoir is at Offord. During high
winter flows more water is pumped into the reservoirs than is taken for supply. When river flows
are low in summer more water is taken for supply than is pumped from the river. The reservoirs
therefore provide security of supply by balancing winter and summer flows. Foxcote supplies
Buckingham, with a relatively small demand, and river flow at this point is sufficient to support
year round abstraction but at Grafham in 1990 the river flow declined so much that, in order to
protect the minimum required flow stipulated in the abstraction licence, it was necessary to cease
abstraction from the river at Offord for Grafham Water altogether for a period. The water used
for supply is treated and returned to the river after use as sewage effluent, thus augmenting river
flow. Grafham water is part of an integrated resource network which includes Rutland Water and
the Pitsford reservoir. This is called the Ruthamford system and supplies a large area extending
beyond the Great Ouse catchment. Up to 60 Ml/day is exported out of the catchment to Lea
Valley Water Company whose supply area includes Luton and Dunstable. The sewage effluent
from Dunstable is returned to the headwaters of the River Ouzel and the effluent from the smaller
of the two Luton sewage works discharges to the Flit, whose waters reach the Bedford Ouse
between Bedford and St Neots. Some towns within the catchment are supplied from Rutland
Water, resulting in a small net import into the catchment. Some water from the network supplies
Bedford and Milton Keynes, upstream of the Grafham intake at Offord, so that a small amount of
water cycles in a loop between Grafham and these two towns. Water is extracted all year round at
Clapham to supply Bedford. Since the river receives effluent from large sewage works at Milton
Keynes and, via the Ouzel, from works at Dunstable and Leighton Linslade, as well as from
several smaller works, all of which are upstream of the Clapham and Offord intakes, there is a
substantial degree of re-use of the river water.

32. The present position

The dependence of the area on the Ouse has led to a great deal of attention being paid to the
management of the river in terms of both the quantity of water available and its quality. The river
receives a substantial volume of sewage effluent (Figure 11), some of which contains industrial
trade wastes. The catchment is largely agricultural so that the drainage waters carry nitrates,
phosphates and other agrochemicals such as pesticides and herbicides which can be found in the
groundwater and in the river. The area is attracting industrial companies and the population in
the Anglian region is increasing more rapidly than anywhere else in the country. In the 1960s
forecasts of water demand predicted a shortfall in water resources in the region and at the same
time proposals to construct a large new town, Milton Keynes, at the headwaters of the river
causd great concern for water quality in the Bedford Ouse. This concern led to the establishment
of the Bedford Ouse Study.

33. The objectives of the Bedford Ouse study were to construct a steady state mathematical
model of water quality in the river; to consider the feasibility of constructing a dynamic model of
the quality in a particular stretch of the river; to develop a set of water quality criteria against
which the projection of the models could be assessed. The models would be used to forecast the
impact on water quality of the projected developments in the catchment over the following two decades on which a management strategy could be based and tested. The study is described in three reports (1975, 1977, 1979). The conclusions were that the models developed were useful tools but needed to be refined and extended in certain respects. The model also revealed a need for quality monitoring in specific areas. The original dynamic model has been extensively modified, developed, and rewritten by the Institute of Hydrology and is now available for general use as QUASAR. Another water quality model, SIMCAT, is used to set consents for discharges and to plan the other measures needed to achieve River Quality Objectives. SIMCAT has been specially written to facilitate better and quicker decisions on consents. QUASAR is used to help set up procedures for dealing with incidents. In 1988 WRc developed a water resource model for the Great Ouse under contract to Anglian Water Authority.

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34. Projections for water demand have proved to be exaggerated, as was the case for Birmingham (see above) and the population of Milton Keynes, for example, was quoted by Hellawell (1986) as 120,000 in 1984 (Table 4 suggests a figure closer to 130,000) compared with a projected 160,000. It is now expected that the town will reach a stable population in the late 1990s, somewhat later than forecast and somewhat smaller than the planned 250,000 (see Table 4). The volume of groundwater abstracted for public supply has remained constant at about 55 Ml/day and the increase in demand within the region has been met by river abstractions which have increased from just over 100 Ml/day in 1970 to just over 200 Ml/day in 1986 (Figure 10). The four dry years of 1973–76 and the 1984 drought are reflected in higher than average surface water abstractions (Figure 10). The volume of groundwater abstracted for spray irrigation has increased from an annual average of about 1 Ml/day in 1970 to about 1.3 Ml/day in 1986. The volume of surface water abstracted for this purpose has increased more rapidly from about 1.5 to 6 Ml/day. The apparently small proportion of total annual abstractions which this represents is misleading since spray irrigation is concentrated in the three months June, July and August at a time when river flows are at their lowest. They therefore represent a significant proportion of total use during these months. Industrial abstractions have declined to low levels.

35. The proportion of effluent flow in the river has risen, reflecting the increase in public supply, from about 11% of the flow at Earith in 1971 to 16% in 1986 (Figure 9). The high proportion of effluent in the flow in 1973 reflects very low flows in the river in that year (Figure 8). There are 112 public sewage works discharging to the Bedford Ouse, most of them relatively small, and numerous private and industrial effluent discharges. (Hydrological data were obtained by running the mathematical resource model of the river constructed by WRc for the Anglian Region of the NRA (NRA, 1990).) The region has, however, the tightest effluent standards in the UK. This is necessary because of the number of large and growing conurbations at the headwaters of the Ouse (Milton Keynes, Buckingham, Hitchin, Biggleswade and others). Their achievement has been made possible partly because the rapid development of housing in the region as population has grown has required new sewage works to be built and operated to high standards. Furthermore, the cost of achieving these high standards has not been an obstacle since it has been small in relation to the total costs of large new developments. Low rainfall in the region means that storm overflows operate less frequently than in wetter areas and their polluting effects are less important although they can be significant, particularly in the wetter upper part of the catchment.

36. Although demand has not reached the levels forecast in the late 1960s, consumption is rising steadily and is likely to continue to increase in the medium term as Milton Keynes grows. The situation has been exacerbated by the fact that rainfall in the area has been well below average for the past three years. In the Ouse as a whole groundwater recharge has failed to match abstraction so that groundwater levels have fallen and, as a consequence, base flows from groundwater to the river have also declined, reducing river flow, particularly in summer. The sources of some of the tributary bournes have moved down their valleys, reflecting the drop in the water table. The situation would be restored if rainfall returned to its historical average levels but this would be an imprudent planning assumption.

37. The quality of the Bedford Ouse is at present class 1B or 2 throughout its length with the exception of a short reach downstream of Brackley which is class 3 but has class 2 as an objective (NRA, 1990). There have been improvements in water quality as measured by biological criteria (Table 5) using BMWP scores (see para 73).

| Table 5 |
| Mean BMWP scores of the Great Ouse 1970–1989 |
| St Neots | 70 | 124 | 142 |
| Godmanchester | 82 | 123 | 132 |

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To much significance should not be attached to small differences in BMWP scores obtained by different groups and the NRA’s view is that there has not been a significant change at these two points throughout the 1980s. The current performance of the river is illustrated in Table 6.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>% Flow complying with RQO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackley</td>
<td>86 (74-94)</td>
</tr>
<tr>
<td>Newport Pagnell</td>
<td>91 (80-97)</td>
</tr>
<tr>
<td>Earth</td>
<td>78 (62-89) (failures probably due to algal growth; NRA, personal communication)</td>
</tr>
</tbody>
</table>

38. Milton Keynes
The construction of a town the size of Milton Keynes just upstream of the confluence of the Rivers Ouzel and Great Ouse at the headwaters of a river as intensively used as the Bedford Ouse, was greeted with some misgivings. The sewage effluent from the expected 250,000 population would increase the load of conservative pollutants and also of non-conservative pollutants at a point some 60 km upstream of the Clapham intake. The town would also create a large impermeable area which would increase run-off. This would increase the risk of flooding and introduce a new polluting load of grime, oil and other materials derived from vehicle emissions and road debris.

39. The principles and details of the design of the Milton Keynes drainage system have been described by Coombes (1986). Great care was taken in planning the sewage system of the town to minimise its impact on downstream river water quality. Separate foul and surface water drains were installed throughout and the need for storm water overflows from the foul sewers has been avoided. The river is protected from the effects of run-off water in two ways.

A. Oil interceptors
Oil pollution was considered to be a serious potential problem and as a first stage it was decided to require oil interceptors to be installed at individual sites, including car parks. The second stage was to install interceptors at the area level, such as at the discharge point from all or part of an industrial estate, to trap oil which had escaped the first stage. Finally, interceptors were to be installed at the entrance to the retention and balancing lakes used to control storm waters. The small amount of oil which has been collected (3 cubic metres in 1984) and the very high capital and operating costs of the interceptors led to a review of this strategy, and a detailed assessment of the requirements. The problem is that during rainfall the high run-off rate from paved areas overwhelms the interceptors at a critical period and they do not function properly.

B. Balancing lakes
The sum of £20 million was spent on the construction of off-line lakes, into which water is diverted when flows reach a certain level and which are allowed to discharge when the river can assimilate the flows, and on-line lakes which have a fixed outflow and whose levels are determined by the inflow. The off-line lakes have been constructed to enhance the environment and are used for recreational activities such as angling, sailing, wind-surfing and bird watching. Some 30–40% of their cost can be attributed to the provision of amenity value.

40. Sewage is screened and de-gritted before primary settlement. Primary sludge is pumped directly to anaerobic digestors. The primary effluent is treated at an activated sludge plant and surplus sludge co-settled in the primary sedimentation tanks. The secondary sewage effluent receives tertiary treatment by rapid gravity sand filtration and the filtered effluent is taken by a 4 km pipeline to maturation lagoons alongside the River Ouse downstream of Newport Pagnell. The retention time is 2–2.5 days before the final effluent is discharged to the Ouse. The Ouse Model was used to predict the effects of the Milton Keynes discharge on downstream water quality and to ensure that the effects would be acceptable. Measurements from 1974 until 1984 at
four downstream points, Old Stratford, Newport Pagnell, Harrold and Bedford, show that water quality has either remained stable or improved slightly and that the model predictions were slightly pessimistic. At Brackley 86% of flows complied with the quality standards, at Newport Pagnell 91% and at Earth 78% (NRA, 1990) (Table 6).

41. The use for recreation of lakes designed as part of the pollution prevention system creates difficulties. After rain, oil which has escaped the interceptors reaches the lake and forms a slick. In addition some storm overflows discharge directly to the lake (as they were designed to) and this can result in aesthetically unsatisfactory conditions. This leads to complaints from those who use the water for recreational purposes. Efforts are being made to deal with the problem but there was a basic conflict of intent at the design stage.

42. There are three aspects of raw water quality which concern the water supplier particularly. These are phosphate, nitrate and pesticides. Nitrate and pesticides are important because the drinking water regulations specify particularly stringent maximum concentrations in potable supply. These two substances derive predominantly from agriculture and reach groundwater and surface waters by mechanisms of diffusion. Urban inputs enter mostly from point discharges and can, at least in principle, be controlled relatively easily, if not cheaply, but it is more difficult to control diffuse inputs where it can be impossible to identify the specific origin of a pollutant. Phosphate is not hazardous to health in itself but it is typically the nutrient whose concentration limits the growth of algae in fresh waters. Increases in phosphate allow a greater biomass of algae to form and this can impede the treatment of water for supply and impart taste or taint to the water after treatment. On occasions certain types of algae may produce substances toxic to fish and mammals and this has occurred in the Bedford Ouse catchment.

43. **Nitrate**

Dr Warn of the Anglian unit of the NRA has kindly provided data on nitrate levels in the River Ouse at Bedford for the past 34 years. A rising trend between about 1965 and 1980 is clearly shown, superimposed on large seasonal fluctuations. In order to compress the large volume of data, to reduce the effects of short-term fluctuations and to overcome the difficulties posed by irregular sampling frequencies, monthly means were calculated. In addition a multiplicative seasonal correction was applied which largely eliminated seasonal variations. A cusum (cumulative sum of variations from the global mean) analysis of the resulting data set was used to identify points at which mean levels changed significantly and the results are shown in Figure 12 in the form of a Manhattan diagram (so-called because of the superficial resemblance of such diagrams to the New York skyline). The rising trend can now be seen to have stopped in about 1975 and, apart from a trough between 1979 and 1981 mean levels seem to have remained fairly constant until mid-1988. There is evidence that levels have fallen since then but only time will tell whether this is another temporary trough or whether levels will continue to fall. Nevertheless, Figure 12 could also be interpreted as showing a more or less linear fall in nitrate levels since 1987 and stricter controls are being applied to the use of nitrate fertiliser. In the last decade nitrate levels have frequently exceeded the 50 mg/l limit of the drinking water regulations and water for Bedford has to be blended with low nitrate supplies (eg Whitehead et al.). It was estimated (Owens and Wood, 1968) that 83% of the nitrogen in the Bedford Ouse came from sources other than sewage effluent and Owens (1970) calculated that 25% of the nitrogen at Tempsford came from sewage effluent on an annual mean basis. These figures have recently been confirmed by modelling using SIMCAT. The sewage input is relatively constant whereas the water supply problems arise in winter when flow and agricultural inputs of N are at a maximum. At this time of year agriculture contributes about 90% of the nitrate in the river. Agriculture is thus the main source and reductions in nitrogen levels depend on controls on agriculture in sensitive areas where nitrogen leaching from the soil contributes the greatest quantities to nitrogen in water used for supply. During reservoir storage nitrate levels tend to decline with a half-life of around 6 months as a result of dilution and by denitrification which occurs in sediments.

44. **Pesticides**

Chlorinated pesticide levels were around 0.02 micrograms/litre in 1970 (Billington, 1970) compared with the present standard for drinking water of 0.1 µg/l but since then the variety of
Figure 12 Monthly nitrate levels in River Ouse (1/1/1957–1/3/1991)

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Pesticides and herbicides in use has expanded, as has the extent of their application. Certain pesticides are now sometimes found at concentrations in excess of 0.1 μg/l (Croll, 1991) and the DoE has set Advisory Values (AVs) for them based on toxicological information. Between 1987 and 1990 levels of atrazine at Clapham ranged from 0.14 to 1.68 μg/l (AV 2); of simazine from less than 0.02 to 1.89 μg/l (AV 10); of mecoprop from less than 0.1 to 2.7 μg/l (AV 10); of isoproturon from less than 0.2 to 5.13 μg/l (AV 4) and of dimethoate from less than 0.02 to 0.941 μg/l (AV 3) (NRA Report). The median levels of pesticides other than atrazine and simazine are very much towards the lower concentrations and the maximum levels recorded are, with the exception of isoproturon on one occasion, well below the DoE Advisory Levels. Concentrations vary considerably from month to month suggesting that surface run-off carries a significant load. Conventional water treatment does not remove pesticides completely. Reliable technology for pesticide removal to attain the EC drinking water standard of 0.1 μg/l is only just emerging from the experimental stage and is complex and expensive to implement. The problem is likely to remain until the use of these substances is brought under control. Some biocides are used in agriculture but atrazine and simazine are used extensively on roadside verges and railway embankments and cuttings as a cheap alternative to manual clearing. British Rail, however, and a number of local authorities have recently agreed to abandon the use of the triazines for this purpose and to use a more expensive but more environmentally acceptable alternative.
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45. Phosphate

In flowing water the concentration of algal biomass which can be reached is limited not simply by phosphate concentration but by the flow. Blue-green algae, for example, grow rapidly only in water which is undisturbed. The river itself supports a large algal population but when impounded under static conditions much more serious problems can arise. Foxcote reservoir is particularly vulnerable being shallow so that the sunlight on which algae depend can penetrate to the bottom, allowing algae to grow throughout the water column. Until 1981 algal blooms occurred in the Foxcote reservoir regularly in summer to the extent that the water could not be used for supply for as much as 6 months of the year. Since then incoming water has been dosed with ferric sulphate which precipitates phosphate as the insoluble ferric phosphate. Internal recycling of phosphate from the sediments delayed improvements for three years but phosphate levels have now fallen and algal blooms no longer prevent the water being used for supply (Young et al., 1988). The removal of plankton domination has, however, allowed higher plants to proliferate in the shallow waters of Foxcote and these cause other problems. Grafham Water is also subject to algal blooms but to a lesser extent since it is larger and deeper than Foxcote (Toms et al.). Phosphate concentrations are of the order of 10 times higher than at Foxcote (Table 7) and dosing with ferric sulphate began in 1990. Phosphate levels should now fall to levels comparable with those at Foxcote. Owens and Wood (1968) estimate that, in contrast to nitrogen, 83% of phosphorus in the Bedford Ouse came from sewage effluents and Owens (1979) calculated that over 90% came from sewage in the Great Ouse at Tempsford. These figures have been confirmed recently by modelling, using SIMCAT. Phosphate can be removed from sewage effluent but it would be impracticable to install tertiary treatment at 112 sewage works. Furthermore, even if this were done phosphate concentrations in the river would still reach levels at which the water would be defined as hypertrophic in terms of its phosphate concentration and would have the potential to support a large algal biomass if impounded or if the river flow declined sufficiently.

<table>
<thead>
<tr>
<th>Table 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate levels in Foxcote and Grafham Water reservoirs 1985–90</td>
</tr>
<tr>
<td>(Parr et al., 1991)</td>
</tr>
<tr>
<td>Reservoir</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Grafham Water</td>
</tr>
</tbody>
</table>

46. Toxic algae

Some species of algae produce toxic substances under certain conditions. Water suppliers are concerned that such toxins may not be removed by treatment and will enter the public supply. The NRA and the Foundation for Water Research are supporting an extensive research programme on algal toxins which includes methods of analysis and technologies for their removal (FWR, 1990; NRA, 1990). The significance of algal toxins in drinking water is difficult to determine and the animal deaths which have occurred seem to have resulted from the actual consumption of algal biomass on the edges of reservoirs. The first step, therefore, is to eliminate the conditions which permit the rapid accumulation of algal biomass and this is being done.

Discussion

47. There are numerous reports on the history and development of the Tame catchment and on the Tame Reclamation Lakes but the literature for the Ouse is less varied. Much of it is concerned with the development of mathematical models and is more theoretical in character. In both cases the volume of published material falls sharply after about 1984 and most of the more recent information about the two rivers was very kindly provided directly by the Severn Trent and Anglian water companies and by the relevant units of the NRA. They also raised in the course of discussions a number of issues which are discussed in this report. Although the report focuses exclusively on two river systems, the Tame and the Bedford Ouse, these two case studies illustrate a number of general issues.
48. **Water quality policy**  
Until the middle of this century river pollution prevention was pragmatic. Measures were taken, where the need was recognised, to maintain the quality of rivers which provided a supply of potable water but elsewhere less attention was paid to pollution prevention. On occasions it proved impossible to ensure protection even of a river which did supply drinking water and sources had to be sought elsewhere, as happened with the Tame in 1872.

49. Standards which effluents from sewage works should meet were first laid down as recommendations by the Royal Commission in 1898. These standards, expressed in terms of suspended solids (SS) and Biochemical Oxygen Demand (BOD), assumed that the discharge would be diluted by the receiving waters at a minimum ratio of 8:1. The Royal Commission standards provided the basic criteria for effluent quality for over three-quarters of a century and to some extent are still used. The rigour with which they have been enforced, however, reflects both the availability of money to improve sewerage systems and the effectiveness of the institutional structures at different periods. The institutional history has been described by Kinnersley (1988) but policy for water quality and for pollution control is also bound up with our understanding of the causes of pollution.

50. It had long been recognised that, apart from SS and BOD, other polluting materials were important in determining the quality of rivers. In addition it was realised that both long-term and short-term effects need to be considered. The biological quality of a river reflects not only the average chemical quality in terms of, for example, the concentrations of pollutants and of dissolved oxygen but also the frequency and severity of short-term excursions from the average as a result, for example, of pollution events during storms or of accidental discharges. Communities of aquatic organisms can sometimes survive short episodes of pollution more severe than they can tolerate in the long term. The requirements that sewage works comply with effluent standards for 95% of the time recognises that sewage works occasionally receive excessive loads, for example, after heavy rain, and may produce poorer quality effluent for a short period without necessarily threatening the biological quality of the receiving waters. In the late 1970s and early 1980s the River Quality Objective (RQO) approach was developed, in which the maximum (or minimum) average concentrations of particular substances which can be permitted in the river (Environmental Quality Standards or EQSs) are determined on the basis of the use to which the water is to be put (potable supply, irrigation, fisheries, etc). This in turn can be used to calculate the maximum quantities of polluting substances which can be discharged without compromising the use of the water. Implicit in this approach is a form of cost-benefit analysis in that, rather than setting universal emission standards, standards for effluent discharges, and thus expenditure on pollution control, are related to the use of the river. EQSs also take account of the background concentrations of pollutants in the water, which arise from natural or uncontrolled inputs, and of the assimilative capacity of the water. The EC Dangerous Substances Directive now allows as alternatives both this approach and the Uniform Emission Standards (UES) approach favoured by Germany and certain other countries. The arguments for and against these two approaches were reviewed by the Royal Commission in its 10th report (1984). The new directive on urban wastewater treatment reverts, however, to specifying emission standards only for BOD, chemical oxygen demand (COD), nitrogen, and phosphate, a step which the House of Lords Select Committee on the Environment has criticised.

51. Whatever the principles used in setting effluent standards they can only be applied to discharges of polluting material from consented point sources where the discharger is clearly identified. They cannot be applied to diffuse sources, such as run-off from agricultural land or from contaminated land, nor to unlicensed discharges, which are often important sources of pollution. Although the EQS approach does take account of diffuse sources the standards themselves can only be used to control point sources.

52. The European Commission has been concerned for some time at the generally slow progress which has been made in Europe in improving river quality and is proposing a new directive which will require countries to define “high” quality targets for all surface waters in terms of “ecological” (biological) criteria. Its intention is to oblige Member States to achieve and to
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maintain surface water quality, irrespective of its use, at this high level (ie as it would be if largely unaffected by anthropogenic influences). A draft of this proposed directive is expected to be published in the Official Journal before the end of 1992.

53. This approach assumes, however, that all sources of pollution can be identified and controlled and it therefore presents special problems for rivers like the Tame. It would scarcely be practicable, even if it were desirable, to return to their pristine state catchments which have been substantially built up and urbanised. The expenditure on the Tame catchment so far of probably in excess of £500 million at 1991 prices has largely dealt with sewage discharges and most industrial discharges to the river have now either ceased or been diverted to sewer. Nevertheless, the river is still class 3 as a result of periodic discharges of polluted storm water, diffuse inputs from contaminated land and occasional unlicensed discharges of industrial waste to the river, to the sewers or to the storm drains, which are much less amenable to control.

54. Storm water and sewer overflows
A substantial reduction in the polluting load carried by discharges of stormwater, or sewer overflows, would require purchases of land for the construction of holding tanks, the large-scale construction of storm sewers and enhancements to sewage works to allow them to deal with the occasional much larger volumes of influent. Even this would not restore the original conditions since rain falling on the catchment would enter the river much further downstream than it would naturally and further diminish river flows in the upper part of the catchment.

55. Contaminated land
The elimination of pollution from contaminated land would be a daunting task, involving the demolition of houses built on contaminated land and the excavation of the underlying soil, irrespective of whether the dwellings themselves or their inhabitants were at risk. It would also require the large-scale excavation and removal of entire landfill sites. In many cases the organisation responsible for contaminating the land no longer exists, or would not have the financial resources to pay for the clean-up operation so that the money would have to be found from other sources. The political and economic practicability of carrying out this work must be in doubt. Furthermore, the work itself, if it were undertaken, would create new pollution and the disposal of the excavated material would also present severe difficulties. One approach which might be applied in some circumstances is the in situ clean-up of contaminated sites using microorganisms.

56. Unlicensed discharges to the river system
It might seem to be a straightforward task to identify illegal discharges and deal with them but in practice the discharges are often intermittent and their effects transient, lasting only for a few hours. To pick them up as they occur would require continuous or frequent monitoring of long reaches of the river system, at closely spaced points. Unlicensed discharges also often involve substances whose identity is not known and the organisation responsible for monitoring would, therefore, have to guess at the substances for which they should analyse. The range of chemicals for which analysis would be needed is very large. For some organic substances the method of analysis is complex (see, for example, Croll, 1991), time-consuming and expensive and the large-scale continuous monitoring of the river system for such a wide range of possible pollutants would be prohibitive in terms of the resources required. Where the unlicensed discharge contributes an incremental amount to a substance already present it is more difficult to identify a particular source with confidence. Much of the River Tame is culverted and it is probable that many of the unlicensed discharges occur in culverted sections which are inaccessible to routine monitoring.

57. Unlicensed discharges to sewers and surface water drains
Unlicensed discharges to sewer may be manifested in the form of occasional problems with the sewage treatment works and/or as occasional failures of the sewage works effluent to meet its consent. In principle the NRA could prosecute the water company in order to provide an incentive for it to locate and control illegal discharges. On the other hand the water company is not itself directly responsible for the failure and the difficulties for the water company are immense, including all those described for detecting discharges to the river with the added
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c complication that the sewer system is entirely underground and not amenable to the kind of intensive monitoring which is, at least in theory, possible for the unculverted sections of the river. Furthermore, it can be argued that the money and resources which would be consumed in prosecution would be better spent on improving the river. It can take years of painstaking detective work to identify with certainty the source of substances which appear intermittently, and then only at concentrations close to the limit of detection of the analytical method. This is evidenced by the (unpublished) experience of the then Yorkshire Water Authority in seeking the source of mothproofing agents detected in the River Aire. In one case at least the discharger himself was unaware that his effluent contained a pesticide since it was present without his knowledge in imported material. Some surface drains receive unlicensed discharges, which cannot be detected by their effects on a sewage works, and which only reveal themselves by their subsequent effects on the river. There are many discharges of surface water and it can be difficult to locate the few which contain material from unlicensed effluents. The problems of finding the unlicensed discharge itself and identifying the person or organisation responsible would then be at least as great as those of locating unlicensed discharges to sewer. Cooperation between the water company and the NRA in deciding on priorities, and in the investigative procedures, is more effective than an adversarial approach.

58. None of these problems is in theory insuperable, given unlimited resources, but the limiting factor is manpower rather than capital. The water company might seek to recover the costs of the detection process from the polluter once he had been identified, but many polluters would not have the financial resources to meet the costs, which would have to be underwritten by the water company’s customers or by the taxpayer.

59. Conclusions
The problem of setting arbitrarily high quality objectives for surface waters is that in some cases the manpower required and the social and financial cost of achieving them would be very great indeed. It is to be hoped that quality targets will recognise intractable local problems which could otherwise consume a disproportionate amount of the available resources in relation to the benefits which could be secured and which on occasions might also create new environmental problems.

60. Sewer system design
The UK has the oldest sewer system in the world. The earliest sewers were built solely for surface water drainage and until 1815 it was illegal to discharge domestic sewage to them. After about 1840 water closets grew in popularity and it became obligatory to discharge to a sewer if one were available. The original sewers were thus “combined” and carried both surface run-off and domestic sewage directly to the river. When rivers became too polluted interceptor sewers were built along the river banks to collect the dry weather flow and convey it to new treatment works downstream of the towns. The original outfalls were retained and, during periods of heavy rain, when the polluting load was so diluted with surface run-off that it had no deleterious effect, the sewage was allowed to overflow into the river. These combined sewers, many still in remarkably good condition, form the backbone of the present sewerage system. In the 1930s as motor vehicles replaced horse-drawn carriages and surface run-off no longer carried residues of dung, separate systems for surface run-off and sewage were installed in new housing estates. Sewage was either conveyed directly to the treatment works or discharged to the top of the old combined sewer and surface drainage was discharged either to the river or sometimes also to the old combined system.

61. As populations grew and built-up areas expanded they outstripped the capacity of the sewerage system and this created problems of two kinds:

- Flooding of streets and property as a result of inadequate sewer capacity, or the inefficient use of capacity.
- Pollution of rivers by inadequately controlled storm overflows, by polluted surface water outfalls or by poor quality effluent from overloaded treatment works.
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These two problems are related in that flooding frequency can be reduced at the expense of river quality by allowing overflows to operate more often. Polluting effects have traditionally been measured in terms of the effect of BOD and ammonia on fish life but indicators of pathogenic organisms, such as faecal coliforms, will become of greater concern as rivers are increasingly used for water contact sports. Now that large sums of money are being spent on refurbishing and reconstructing sewerage systems and on building new systems for new towns the question arises of whether to use combined systems, or to employ some form of separation of foul water from surface water or to develop novel approaches to solving the problem. The desirability and practicability of treating or disinfesting combined sewer overflows and surface water outfall discharges is being discussed and, if European pressure for this solution intensifies the balance would tilt in favour of combined sewers or towards novel approaches. Combined systems are also more effective in dealing with chemical spills on the highway since polluting material can be washed into the sewers in the certainty that it will be treated before release to surface waters.

62. Current practice throughout the developed world is to install separate systems on greenfield sites. Where the geology is suitable roof drainage may be led to soakaways for groundwater recharge. When the Water Authorities were formed in 1974 they followed the recommendations of the Final Report to the Technical Committee on Storm Overflows and the Disposal of Storm Sewage (1970), which had concluded that “It would be generally undesirable to adopt a policy which resulted in the construction of new sewerage systems with storm overflows” but that “It would be unrealistic to contemplate eliminating, over the next few decades, all storm overflows…” although “…the opportunity might be taken in redevelopment schemes to separate surface water in whole or in part”. This opportunistic approach has been questioned in recent years and current policy is to maintain and refurbish existing combined systems, mitigating the problems of flooding by maximising the use of sewer capacity and installing flow detention tanks within the sewerage system.

63. Alternative approaches

In areas of terraced housing a “partially separate” system is sometimes used in which a combined sewer at the rear collects foul sewage and drainage from the yard and rear roofs and a surface water sewer at the front collects road run-off and the balance of the roof drainage. In regions subject to extreme storms, such as the eastern seaboard of Australia and sub-tropical USA, a “Major/Minor” system is sometimes used in which combined sewers carry foul sewage and frequent low-intensity rainfall, but the points of entry of storm water are throttled so that excess flows during severe storms are retained in natural drainage channels which predate urban development, rather than being decanted through storm overflows. This type of system has not found favour in Europe.

64. Tables 8–11 show the theoretical performance of the different systems for a hypothetical town of 50,000 population covering an area of 1,000 ha, of which 25% is paved. It is assumed that foul sewage flow is 250 l/h/d and mean annual rainfall is 700 mm.

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Pollutant concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>5-day BOD (mg/l)</td>
</tr>
<tr>
<td>Raw sewage</td>
<td>400</td>
</tr>
<tr>
<td>Overflow spill</td>
<td>100</td>
</tr>
<tr>
<td>Surface run-off</td>
<td>15</td>
</tr>
<tr>
<td>Treatment works effluent</td>
<td>15</td>
</tr>
</tbody>
</table>

(Assuming that sewage in spill is diluted 1:12)
Table 9
Performance of different sewerage systems — flows (m³/year)

<table>
<thead>
<tr>
<th>System</th>
<th>Flow to treatment works</th>
<th>Flow to receiving water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate</td>
<td>45.6</td>
<td>17.5</td>
</tr>
<tr>
<td>Combined</td>
<td>59.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Partially separate</td>
<td>51.7</td>
<td>11.4 (1.4 via overflows)</td>
</tr>
<tr>
<td>Major/minor</td>
<td>59.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

(Assuming that overflows are set to operate 100 hrs/year)

Table 10
Relative costs different sewerage systems

<table>
<thead>
<tr>
<th>System</th>
<th>Relative cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate</td>
<td>2.10</td>
</tr>
<tr>
<td>Combined</td>
<td>1.38</td>
</tr>
<tr>
<td>Partially separate</td>
<td>1.68</td>
</tr>
<tr>
<td>Major/minor</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 11
Performance of different sewerage systems — pollutant load discharged to receiving water

<table>
<thead>
<tr>
<th>System</th>
<th>Source</th>
<th>BOD (kg/year)</th>
<th>Faecal coliforms (10⁹/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate</td>
<td>Sewage effluent</td>
<td>68,400</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Surface drainage</td>
<td>26,300</td>
<td>875</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>94,700</td>
<td>884</td>
</tr>
<tr>
<td>Combined</td>
<td>Sewage effluent</td>
<td>89,400</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Storm overflows</td>
<td>35,000</td>
<td>1,225</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>124,400</td>
<td>1,237</td>
</tr>
<tr>
<td>Combined (with detention tanks)</td>
<td>Sewage effluent</td>
<td>94,500</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Storm overflows</td>
<td>negligible*</td>
<td>negligible*</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>94,500</td>
<td>13</td>
</tr>
<tr>
<td>Partially separate</td>
<td>Sewage effluent</td>
<td>76,700</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Surface drainage</td>
<td>15,000</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Storm overflows</td>
<td>14,000</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>105,700</td>
<td>1,000</td>
</tr>
<tr>
<td>Major/minor</td>
<td>Sewage effluent</td>
<td>89,400</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Surface drainage</td>
<td>5,300</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>94,700</td>
<td>187</td>
</tr>
</tbody>
</table>

* Depending on the capacity of the detention tanks.

65. Too much importance should not be attached to the precise numbers derived for a purely hypothetical example but they do give an indication of the relative costs and effectiveness of different systems and allow certain tentative conclusions to be drawn:

- The polluting load discharged by separate systems is around 25% lower than that from a combined system but the cost is some 50% higher.
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- The provision of detention tanks on a combined system reduces the polluting discharge to the same level as that of a separate system, with even greater benefit to coliform discharges, but with negligible increase in cost ratio, and they can be fitted retrospectively.

- The Major/Minor system is probably the most cost-effective but cannot be retrofitted and must be built in at the construction stage, when it imposes severe planning constraints.

It must be recognised that as few as 1.25% of wrong connections of foul sewers to storm drains can nullify the environmental benefits of separate systems (SDD, 1977).

66. Modern modelling techniques allow accurate sizing of detention tanks to achieve any level of performance in flood protection or pollution prevention specified by the user. There is no longer any need, therefore, to specify a particular sewerage system and the engineer can safely be allowed to choose the most cost-effective way of meeting the user’s requirements.

67. Novel approaches
Toilet flushing comprises 32% of domestic water use (WAA, 1988) but contributes to the sewage stream 59% of the organic carbon (BOD load) (Painter and Viney, 1959) and virtually all the faecal coliforms (Siegrist, 1976). There would thus be advantages if the flow from toilets could be conveyed separately to the treatment works. This would greatly reduce the pollutant load discharged from combined sewers in storm overflows. Such a system might be used on new developments but retrofitting would require extensive modifications to existing domestic plumbing and sewerage systems, although the use of small bore vacuum systems, which have been developed recently, installed within the existing sewers offers a possible solution to this. Another possibility would be to carry out some degree of sewage treatment by, for example, air injection, in the upper parts of the sewer system. This would reduce both BOD and coliform levels but would generate sludge in the sewers which would have to be removed, although small-bore vacuum systems might be suitable for conveying this sludge to the treatment works.

68. Conclusions
For existing systems the provision of additional storage capacity to retain high flows is likely to be the most cost-effective method of reducing both flooding and the polluting load discharged in storm overflows. Separate systems offer more effective control in theory, albeit at significantly higher cost, but in practice even a small proportion of wrong connections to the surface drains can vitiate these benefits. In general, designing to meet specific requirements is likely to be more cost-effective than a prescriptive approach. Radical approaches such as the separation of toilet flushes from other waters may offer potentially greatly improved performance for new developments. Separating toilet flushes would involve making modifications to domestic waste water systems, the cost and practicability of which would vary from house to house, but the use of small-bore vacuum systems within the existing sewers might make it possible to retrofit the technology without the difficulties and cost of extensive resewering.

69. Interdependence of water quality and water quantity
Water quality and water quantity are closely connected. For example, water abstracted from a river for supply may be returned after use but will carry, however well it has been treated, a higher concentration of contaminants than that normally found in the river. Abstraction from the river or from groundwater affects river flow to an extent which depends on whether and where the water is returned to the river as effluent. Rainfall exerts a large influence on river flows. Reduced flows diminish the volume of water available to dilute pollutants. Thus, in order to protect the quality of a river, the standards for effluents discharged to it will have to be made more stringent if flow is reduced or if more water is to be taken from the river for supply and returned as effluent. Reduced flow also increases the impact of storm overflows and diffuse inputs on a river, on which stringent standards cannot so readily be imposed.

70. The long-term trends in the concentration of nitrate in the Ouse have been discussed earlier but the causes underlying the changes were not considered. The concentration of nitrate is
determined both by the amount of nitrate entering the river and by the flow (i.e. the amount of water available to dilute it). Figure 13 shows monthly mean concentration (continuous line) and annual means (histogram) of flow-weighted nitrate concentration in the Ouse at Bedford. To obtain flow-weighted concentrations the actual concentration is multiplied by the flow at that time. The purpose is to scale concentration measurements according to their real contribution to total load. The peak in flow-weighted mean in 1976/77 is superimposed on a more or less steadily rising trend in annual mean up till 1987. Figure 14 shows the monthly load in the river (continuous line) and annual load of nitrate (histogram), obtained by multiplying monthly flow and monthly concentration. There is no peak in annual load in 1976, although there is in 1977, and there is no rising trend after 1980. Examination of the figures suggests that, when the drought broke in 1976, rain washed substantial quantities of nitrate off the fields and into the rivers. This had a small impact in 1976 in terms of nitrate load because river flows did not rise significantly until December but had a large impact in 1977. Since the total nitrate load carried by the river remained more or less constant between 1980 and 1987, the rising trend in flow weighted concentration during this period may be attributable to reduced river flows (as a result of lower rainfall, not of increased abstraction from the river) providing less dilution of the nitrate, rather than to an increase in nitrate inputs. Future concentrations of nitrate in the river will depend on climatic factors (water quantity) as well as on nitrate inputs.

71. The value of a water resource depends not only on the volume available but also on its quality, particularly when it suffers from short-term variability. Rainfall produces highly polluting transient flows in the Tame which in turn used to give rise to episodes of low quality in the Trent downstream of its confluence with the Tame. Apart from their effects on the fisheries of the Trent they prevented its use as a water resource for supply. Interestingly, although the investment in improving the Tame, particularly the reclamation lakes, was not made with a view to allowing water to be taken from the Trent for supply, it has contributed substantially to an improvement in the quality of the Trent, and to the elimination of episodes of pollution, which now makes it possible to consider abstracting water from the Trent to supply, directly or indirectly, the growing demand in the Anglian region.

72. A decision to increase abstraction from a water body for supply may have implications for the consents for effluent discharges to the water body, for the control of storm water discharges and for the extent of treatment which the water must receive before it can be put into supply.

73. Measuring water quality

Water pollution is manifested through its effects on aquatic life, on human health and on amenity values (the quality of life) but it has largely been monitored and studied by analysing chemical variables. This stems from the fact that chemical measurements can be made relatively easily and that, in the past, severe pollution incidents were investigated by chemists (Hellawell, 1978). In recent years biological assessment schemes have begun to play a larger part in the classification of water quality. The method employed by the NRA now involves the derivation of a "score" according to a scheme developed by the Biological Monitoring Working Party, known as the BMWP score. Kick samples are taken by disturbing (or kicking) the bed of the water course and collecting the suspended matter in an FBA standard net placed just downstream. The collected material is examined for macroinvertebrates and a list is drawn up of the taxa which are present. Sensitive species are accorded a higher score than less sensitive species. A high total score represents the presence of a sensitive community of high diversity and a low score a tolerant community of low diversity. This process compresses ecological information but provides a numerical value which can readily be interpreted by non-biologists although allowance must be made for the reproducibility of scores obtained in this way.

74. There have been arguments for and against biological and chemical methods of assessing water quality. Biological criteria are defended on the grounds that they effectively integrate the effects of all chemical components of the water, including those which have not been identified or are not routinely monitored. They also reveal the consequences of changes in flow which are not reflected in water chemistry. Chemical criteria are defended on the grounds that biological measurements are intrinsically imprecise; that populations of organisms fluctuate naturally
Figure 13  Nitrate concentration at Bedford
Figure 14  Nitrate load at Bedford
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irrespective of any human interference; and that it is impracticable to set standards for the quality of effluents and monitor day-to-day compliance effectively on the basis of their effects on the biological quality of the receiving water.

75. It is now recognised that chemical and biological measures of quality are complementary and not alternatives. Biological quality measurements are an essential guide to the health of a river and a discrepancy between the biological quality and the apparent chemical quality can give a warning that an unknown pollutant may be affecting a river. Fish kills often give the first warning of a serious pollution incident but biological methods of measuring water quality are in general more labour intensive, and thus more expensive, and are not well suited to detect small changes in water quality over a short period of time. There is, however, a high correlation between the critical chemical components of water (dissolved oxygen/BOD, ammonia, pH, conductivity) and biological quality. Chemical measurements can be made frequently, or even continuously, and can detect very small changes quickly. River quality models can be used to derive chemical standards for effluents relatively easily from the chemical composition of the receiving water.

76. Consents based on effluent toxicity

Although consents for discharges of effluents have until recently always been expressed in terms of limits on the chemical composition of the effluent, such consents are difficult to apply to effluents which are of complex composition, or which contain a range of substances not all of which can be identified with certainty, or which contain substances whose toxicity to aquatic organisms has not been properly established. This has led to the development of methods for determining consents which are based on the toxicity of the effluent (Hunt et al., 1991).

77. A preliminary review is conducted of the composition of the effluent and of the nature of the waters into which it will be discharged in order to establish whether a toxicity-based consent would be appropriate. If so the effluent is screened at a series of increasing dilutions using a simple, rapid and cost-effective test. One such test makes use of a commercially available instrument which measures the effect of a test sample on the photo-luminescence of a population of suitable micro-organisms under standard conditions. The dilution at which a standard effect is produced (eg a 50% reduction in light output) is compared with the dilution which would arise at the discharge point. If effects are observed only at much lower dilutions then a toxicity-based consent might be deemed unnecessary. If effects are observed at higher dilutions then further more sophisticated tests are carried out to determine the effect of the effluent on three aquatic organisms appropriate to the type of receiving waters. The results are used to calibrate the method used for the screening test and to determine a consent for the effluent in terms of the maximum dilution above which a given level of response in the instrument must not be exceeded. The effluent quality is monitored routinely using the method used to determine the consent. The toxicity test forms only one element of the consent, which will also include standards for relevant chemical constituents of the effluent.

78. The process of setting and monitoring a toxicity-based consent is somewhat more time-consuming and expensive than for a conventional consent for a simple effluent but almost certainly easier and cheaper than the elaborate analytical procedures which would be necessary to set and monitor a purely chemical consent for a complex effluent. Toxicity-based consents are used by the Anglian and Welsh regions of the NRA and by the Clyde River Purification Board, mainly for effluents from factories belonging to relatively large companies. At present the NRA and the CRPB bear the cost of setting and monitoring the consents but in future they will be able to recover these costs from the discharger. A toxicity-based element could be used in consents for sewage works effluents, which may contain the soluble and recalcitrant fraction of industrial effluents discharged to sewer, but the water company operating the works has no day-to-day control over what is discharged to sewer and would be unable to respond quickly to a failure to meet its consent. So far no prosecution has been instigated for a discharge failing the toxicity component of its consent. Consents of this kind were introduced in the USA in 1986 and within two years 60% of industrial discharges and 10% of sewage effluents had toxicity-based consents.

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79. River quality classification

The existing River Classification Scheme (Annex), which is based on chemical criteria, has been criticised on several grounds. One is that the classification bands are broad and one river can deteriorate significantly and yet remain within the same classification band while another can suffer only a small deterioration and drop a class. Perceptions of river quality relate to its appearance and to the diversity of life which it supports, but it is less easy to develop a classification scheme based on biological criteria. One problem is that rivers of different types support different species, even in the absence of pollution, and different types of rivers, and different reaches of a single river, will have different BMWP scores. The invertebrate population of a fast flowing mountain stream, for example, will be different from that of a slower moving chalk stream. BMWP scores alone cannot therefore form the basis of a river quality classification scheme. There are several possibilities but one promising approach is to compare the observed BMWP score (or average score per taxon, ASPT) of a river with what would be expected of the same river if it were unmodified by the activities of man. The difficulty is that for many rivers, especially the lowland rivers, no comparable unpolluted river exists which could provide a basis for comparison.

80. The Freshwater Biological Association, now the NERC Institute of Freshwater Ecology, began in 1977 a study of the invertebrate species present in a range of different habitat types at points considered to be relatively uncontaminated (Wright et al., 1989). Statistical techniques were then used to establish correlations between the presence of particular species and certain characteristics of the river such as altitude, depth, substratum composition, alkalinity and so on (Armitage et al., 1987; Moss et al., 1987). These correlations are used to predict the species which ought to be present in any river on the basis of its physico-chemical characteristics and can give a predicted BMWP score. The mathematical model which has been developed to do this is known as RIVPACS (River InVertebrate Prediction and Classification System) and offers an objective method of assessing the biological quality of rivers. Nevertheless, the validity of its predicted BMWP scores depends on a number of factors including:

(i) the number of sites originally surveyed to provide the basic data;
(ii) the extent to which these habitats are representative of the range of habitats to which the predictive method will be applied;
(iii) the degree to which the original samples were truly representative of the habitat at the time they were taken;
(iv) whether the habitats were really uncontaminated;
(v) the strength, and thus the reliability, of the correlations which were established between groups of physio-chemical characteristics and the presence of particular species;
(vi) variations in sampling, sorting and identification efficiencies between the workers who carried out the sampling;
(vii) the nature and validity of any assumptions which are explicit or implicit in the procedures.

81. There were some reservations about early versions of RIVPACS and there were instances where the model predicted significantly lower BMWP scores than were observed. Since then, however, the original RIVPACS database of 268 sites on 41 river systems has been extended considerably and headwater and lowland river sites included. Twenty thousand macro-invertebrate samples are now being collected for the purpose of comparing observed and predicted BMWP scores. Nevertheless, in comparing scores account must be taken of the uncertainties present in each step in the RIVPACS predictive process and also of the measurements made on the test sample. RIVPACS itself does give an estimate of the confidence limits of its predictions. It is also fair to point out that there are uncertainties in the chemical measurements used in the current river classification scheme, both in the analytical procedures and because river water chemistry is variable in space and time.

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82. It is not yet clear whether a statutory river quality objective could legally be based on the predictions of a mathematical model. Even if it could, and could be so worded as to incorporate in some way the uncertainties implied by the confidence limits, the significance of an apparent failure to meet the RIVPACS-based criteria might be challenged. If RIVPACS is to be used to set river quality objectives it will have to be shown that it generates predictions which are routinely consistent with observations over a wide range of rivers and habitats; that the confidence limits of its prediction are acceptably narrow; and that it gives an acceptable level of discrimination between rivers of different physico-chemical characteristics.

83. **Mathematical models**

Investments in water have a long life and it is highly desirable that they should take account as far as possible of future changes. Engineers therefore require the most reliable forecasts which are available. Until adequate computer power became available forecasts could only be made on the basis of statistical analyses of historic data, tempered sometimes by an understanding of some of the underlying factors, or by mathematical models whose complexity was limited by the need to carry out the calculations manually. The advent of computers encouraged the development of much more sophisticated mathematical models of rivers. Empirical models depend on finding mathematical expressions which adequately describe historical data. Conceptual models use mathematical expressions to describe the main processes occurring in the river and their interactions.

84. Models can only approximately describe the enormous variety of complex processes which occur in a river but great efforts have been made to refine and elaborate models and to include more and more processes within the model to try and produce an ever better representation of reality. Indeed, it might be argued that, for a time, a preoccupation with the techniques of modelling sometimes distracted attention from the model's purpose and led to a degree of sophistication which was not justified. No model was needed to identify the remedial measures required to improve the condition of the Tame. The only issues were the choice of engineering solution and the availability of finance. It was less easy, however, to forecast the effect of Milton Keynes on the Bedford Ouse and a large and complex model was constructed over a period of years in order to provide a secure foundation for determining the standards which effluents would have to meet in order to protect the supply of potable water. Such models were costly to develop and could only be run by specialists on what were at the time large computers. Their accessibility was therefore restricted, which limited their use. Many of the models now in use, however, run rapidly on personal computers and the use of models as a management tool is now almost universal.

85. **Amenity value of functional water bodies**

Lakes and lagoons can be a very effective way of providing a buffer for water storage in order to prevent flooding downstream, or to allow time for natural processes to attenuate pollutants. Lakes created in the vicinity of an urban area, however, particularly one far from the sea, are likely to be regarded by the public as amenities even when they are intended to perform a more utilitarian function. This is true of the surface drainage detention lake at Milton Keynes and the Tame Reclamation Lakes at Lea Marston. Such lakes are often landscaped to improve their visual appearance but their very attractiveness may encourage their use for purposes which are not compatible with their primary function. The appearance on occasions of, for example, oil slicks or visible evidence of a polluted water discharge can then give rise to complaints. This problem is not confined to standing water bodies and may also occur with canals. While it is commendable to make a large physical structure such as a lake as attractive to look at as possible, care needs to be taken not to encourage unreasonable public expectations regarding the quality of the water and the recreational purposes for which it can safely be used.

86. **Past and future**

In a densely-populated country the more or less intensive use of water resources is inevitable. We need to manage carefully our use of water in order to conserve resources and to protect water quality but we cannot avoid making some impact on the aquatic environment. Responding to the growing demand for water has required some very large-scale engineering work for water storage
and transfer. Many of the problems which now exercise us stem from instances of mismanagement, lack of foresight, neglect and ignorance in water management before the middle of this century. The cost of dealing with the consequent, sometimes intractable, problems is in many cases almost certainly far greater than would have been the cost of avoiding them in the first place. We now have the institutions, the sources of finance and the management skills to ensure that we do not repeat past mistakes but we must recognise that our aquatic environment is inevitably intensively managed and that some decisions involve inescapable choices and compromises between competing needs and aspirations.

References
Billiongton, R.H. (1970) Quality control of water resources in a River Authority area, Water Pollution Control, 69, 571.
Hellawell, J.M. (1978) Biological surveillance of rivers. NERC.
National Rivers Authority (1990) A resource model of the Great Ouse river system. Report to the NRA by WRC, CO 2504-M.
Appendix 5

Water Resources Board (1973) The Trent Research Programme. HMSO.
### ANNEX

**River Quality Classification**

<table>
<thead>
<tr>
<th>River Class</th>
<th>Quality criteria</th>
<th>Remarks</th>
<th>Current potential uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A Good Quality</td>
<td>Class limiting criteria (95 percentile)</td>
<td>(i) Average BOD probably not greater than 1.5 mg/l</td>
<td>(i) Water of high quality suitable for potable supply abstractions and for all other abstractions</td>
</tr>
<tr>
<td></td>
<td>(i) Dissolved oxygen saturation greater than 80%</td>
<td>(ii) Visible evidence of pollution should be absent</td>
<td>(ii) Game or other high class fisheries</td>
</tr>
<tr>
<td></td>
<td>(ii) Biochemical oxygen demand not greater than 3 mg/l</td>
<td></td>
<td>(iii) High amenity value</td>
</tr>
<tr>
<td></td>
<td>(iii) Ammonia not greater than 0.4 mg/l</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iv) Where the water is abstracted for drinking water, it complies with requirements for A2* water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B Good Quality</td>
<td>(i) DO greater than 60% saturation</td>
<td>(i) Average BOD probably not greater than 2 mg/l</td>
<td>Water of less high quality than Class 1A but usable for substantially the same purposes</td>
</tr>
<tr>
<td></td>
<td>(ii) BOD not greater than 3 mg/l</td>
<td>(ii) Average ammonia probably not greater than 0.5 mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iii) Ammonia not greater than 0.9 mg/l</td>
<td>(iii) Visible evidence of pollution should be absent</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iv) Where water is abstracted for drinking water, it complies with the requirements for A2* water</td>
<td>(iv) Waters of high quality which cannot be placed in Class 1A because of the high proportion of high quality effluent present or because of the effect of physical factors such as canalisation, low gradient or eutrophication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)</td>
<td>(v) Class 1A and Class 1B together are essentially the Class 1 of the River Pollution Survey (RPS)</td>
<td></td>
</tr>
<tr>
<td>2 Fair Quality</td>
<td>(i) DO greater than 40% saturation</td>
<td>(i) Average BOD probably not greater than 3 mg/l</td>
<td>(i) Waters suitable for potable supply after advanced treatment</td>
</tr>
<tr>
<td></td>
<td>(ii) BOD not greater than 9 mg/l</td>
<td>(ii) Similar to Class 2 of RPS</td>
<td>(ii) Supporting reasonably good coarse fisheries</td>
</tr>
<tr>
<td></td>
<td>(iii) Ammonia not greater than 9.9 mg/l</td>
<td>(iii) Water not showing physical signs of pollution other than humic colouration and a little foaming below weirs</td>
<td>(iii) Moderate amenity value</td>
</tr>
<tr>
<td></td>
<td>(iv) Where water is abstracted for drinking water, it complies with the requirements for A3* water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(v) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures not available)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Poor Quality</td>
<td>(i) DO greater than 10% saturation</td>
<td>Similar to Class 3 of RPS</td>
<td>Waters which are polluted to an extent that fish are absent or only sporadically present. May be used for low grade industrial abstraction purposes. Considerable potential for further use if cleaned up</td>
</tr>
<tr>
<td></td>
<td>(ii) Not likely to be anaerobic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iii) BOD not greater than 17 mg/l</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This may not apply if there is a high degree of re-aeration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Bad Quality</td>
<td>Waters which are inferior to Class 3 in terms of dissolved oxygen and likely to be anaerobic at times</td>
<td>Similar to Class 4 of RPS</td>
<td>Waters which are grossly polluted and are likely to cause nuisance</td>
</tr>
<tr>
<td>X</td>
<td>DO greater than 10% saturation</td>
<td>Insignificant watercourses and ditches not usable, where the objective is simply to prevent nuisance developing</td>
<td></td>
</tr>
</tbody>
</table>


Notes:

(a) Under extreme weather conditions (eg flood, drought, freeze-up), or when dominated by plant growth, or by aquatic plant decay, rivers usually in Class 1, 2 and 3 may have BODs and dissolved oxygen levels, or ammonia content outside the stated levels for those Classes. When this occurs the cause should be stated along with analytical results.

(b) The BOD determinations refer to 5-day carbonaceous BOD (ATU). Ammonia figures are expressed as NH₃.

(c) In most instances the chemical classification given above will be suitable. However, the basis of the classification is restricted to a finite number of chemical determinands and there may be a few cases where the presence of a chemical substance other than those used in the classification markedly reduces the quality of the water. In such cases, the quality classification of the water should be down-graded on the basis of biota actually present, and the reasons stated.

(d) EIFAC (European Inland Fisheries Advisory Commission) limits should be expressed as 95 percentile limits.
APPENDIX 6

FRESHWATER AND EFFLUENT QUALITY MONITORING

December 1991
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Aspects of sampling programme design

Appreciating sampling error

1.1 A major obstacle to rational progress in the area of sampling programme design is the failure to appreciate the difference between:

- the *sample estimate* — any quantity calculated from a set of sample results; and
- the *population parameter* — the unknown true value that could only ever be obtained by continuous, error-free monitoring.

The point can be illustrated with the example of ammonia concentrations in a river. A plausible statistical model for the random variations shown by river ammonia concentrations over the period of a year is illustrated in Figure 1. The height of the curve at any point along the concentration axis shows the relative frequency with which that particular ammonia concentration will occur in the river. Thus, the most common concentrations are in the vicinity of 0.05 mg/l; but because of the highly skewed nature of the curve, values as high as 1.0 mg/l and beyond can occasionally occur.

1.2 One parameter of special interest is the 95%ile concentration — the level that ammonia quality stays below for 95% of the time. The 95%ile is important because it is one of the criteria by

![Ammonia Concentration Distribution](image)

**Figure 1** Typical ammonia concentrations in a river, as represented by a log-Normal distribution with mean 0.21 mg/l and st. dev. 0.27 mg/l

**Relative frequency**

**True mean = 0.21**

**True 95%ile = 0.65**

Class

<table>
<thead>
<tr>
<th>Boundaries for 95%ile</th>
<th>boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>1B</td>
</tr>
<tr>
<td>0.4</td>
<td>0.9</td>
</tr>
<tr>
<td>ammonia:</td>
<td></td>
</tr>
</tbody>
</table>

90% probability interval for estimated 95%ile...

- when \( n = 12 \):  
  <xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx>
- when \( n = 36 \):  
  <xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx>
which the river's class is determined. For this hypothetical river sampling point, we have arranged for the 95\%ile ammonia concentration, 0.65 mg/l, to be exactly in the middle of Class 1B — the limits for which are 0.4 mg/l at the 1A/1B boundary, and 0.9 mg/l at the 1B/2 boundary.

1.3 Figure 1 shows the variability truly occurring in the river. In reality we do not know the mean, the 95\%ile or any other parameter. We seek to estimate them via sampling. Suppose we are interested in estimating the 95\%ile for such a river, from 12 samples taken at random over the period of a year. It can be calculated that the estimate may fall anywhere in the range 0.3 to 1.3 mg/l — and, furthermore, that one time in 10 it will be still more extreme. In any one year, therefore, the estimate is almost certain to differ, perhaps by a substantial amount, from the true value. This discrepancy between estimate and truth is what is termed sampling error.

1.4 One consequence of sampling error in this particular example is that there is a sizeable risk (the actual figure is about four times in 10) that the 95\%ile estimate, if taken at face value, would lead to an incorrect classification. We should note, furthermore, that the true 95\%ile concentration will not in general lie exactly at the midpoint of the class. Thus, the risk of misclassification on the basis of 12 samples will in practice be even greater than it is in this example.

1.5 A common practice is to judge river quality on a rolling three-year basis so that the assessment can be based on a more substantial number of samples. In doing this, the presumption (not always tested — or indeed, borne out by events) is that the underlying distribution of water quality remains essentially unchanged over the three years. In cases where such aggregation is valid, the corresponding approximate 90\% probability interval for 36 samples is 0.4 to 1.0 mg/l. Thus, the effect of a three-fold increase in the number of samples is nearly to halve the range of uncertainty. But although this is clearly an improvement, there still remains an appreciable risk (about three times in 20) of the river being incorrectly classified. And as before, the risk will be greater for rivers not positioned centrally within the class.

1.6 In summary, therefore, it is unwise to suppose that any result derived from one particular set of samples constitutes "the truth". To do so is to waste much time looking for reasons for apparent deteriorations and improvements that are due solely to the workings of chance. In the context of river quality assessment this danger was clearly identified in the mid-1980s by a Water Authorities Association working group, and the method for detecting trends in river quality proposed in that group's report [1] has since been endorsed by the NRA. As far as the 1990 river quality survey is concerned, however, no explicit procedure seems to have been built in for handling sampling error, and this is likely to make the definition of "baseline" quality more erratic than would be desirable.

1.7 With effluent sampling, there seems generally to have been a greater appreciation of the existence and consequences of sampling error. One reason for this is the introduction by DoE in 1985 of the so-called look-up table for judging effluent compliance. This is a system which recognises and makes explicit allowance for sampling error in judging compliance with a 95\%ile standard. We discuss the principle underpinning the look-up table further in para 1.30.

Turning data into information, and DRIPS

1.8 The process of drawing inferences from a set of sample results about the underlying statistical population can usefully be regarded as the turning of data into information. Viewed collectively, data is merely the set of numbers derived from the chemical analysis of a number of samples; information is what can be learnt from those numbers about the underlying quality population through subjecting them to a suitable form of statistical analysis.

1.9 A great quantity of historical freshwater and effluent quality data is held on computer archives by the water companies — a legacy of the routine sampling activities of the former water authorities during the period from their formation in 1974 to privatisation in 1989. For rivers, the most common routine chemical determinands are BOD, dissolved oxygen, ammonia,
suspended solids, pH and temperature. For effluents, BOD and suspended solids are often the only two routinely measured determinands; ammonia is, however, generally measured also for effluents from the larger or more important treatment works.

1.10 In the years during which all this data was steadily being accumulated on quality archives, little concerted progress seems to have been made on turning it into information. The computer analysis routines typically available within the water authorities would merely calculate a standard set of summary statistics over the requested time period, with scant attempt made to provide additional graphical or statistical insight into the reliability of those statistics. This shortcoming was exacerbated by the fact that so few potential users of the data possessed sufficient statistical and computing expertise to take matters into their own hands and develop more appropriate software.

1.11 Failure to use its water quality data to full advantage was not, however, a phenomenon peculiar to the UK water industry. In 1986 a paper appeared entitled “The Data-Rich but Information-Poor Syndrome in Water Quality Monitoring” [2]. The authors of the “DRIPS” paper had had considerable experience in the designing of water quality networks in the United States and New Zealand, and they had come to realise that the under-utilisation of water quality data was a universal problem. They identified one crucial weak link in sampling programme design. Monitoring agencies almost invariably failed to specify as an integral part of the programme the mechanisms by which the forthcoming data should be interpreted — the statistical techniques, the computer software, and the nature and timing of analysis and reporting procedures.

**Defining the objective**

1.12 To be able to specify the required statistical procedures, of course, it is first necessary to have established an unambiguous, quantitative statement of the sampling programme objective. Often, therefore, DRIPS is not the root cause of the problem but rather the consequence of an inadequately framed objective. For example, it is easy to declare, both for effluent discharges and for freshwaters, that the principal reasons for sampling are:

- to assess current quality;
- to detect trends in quality; and
- to monitor for compliance with standards.

1.13 These are useful as broad statements of purpose. However, to determine the amount of sampling required, the objective must be expressed in more detailed and quantitative terms. Suppose, for example, that the aim were to estimate next year’s mean BOD at a particular point in a river. This aim could be achieved whether the number of samples was four, 12 or 52. To progress further, therefore, we must specify by how much we are willing to tolerate our estimate being in error. This is where a major difficulty arises. The planner must choose two quantities — the desired precision (±10%? ±20%?) and the desired confidence (90%? 95%? 99%?) — in order to arrive at a specification such as:

> “Mean BOD must be determined to within ±20% with 90% confidence.”

Even should statistical advice be close at hand, the quality planner is easily discouraged by the terminology in which this complicated process of choice is couched, and the whole exercise can seem frustratingly arbitrary. It is hardly surprising, therefore, that those concerned with sampling programme design so often abandon the task and take the easier option of historical precedent.

1.14 This serious practical obstacle has been identified very clearly in a recent publication by WRc on the design of water quality sampling programmes [3]. During the course of many collaborative studies with the water undertakings, the solution we adopted was to put to one side the question of what the future objective should be, and instead to discover, by an examination of available data, what objectives could have been met in the past. To aid this process of enquiry, we developed various computer programs that were tailored specifically to the types of questions that water quality planners most commonly needed to address. The aim was to demonstrate the nature
Appendix 6

of, and limits to, the information that they could realistically hope to extract from their past archive data: given that firm base in reality, they would then be in a much stronger position to set realistically attainable objectives for the future.

Deficiencies of existing freshwater and effluent quality data

1.15 We can examine the relevance and scope of the existing body of water quality data under a number of headings.

Locations

1.16 Most existing river sampling points were originally chosen with convenience of access a prime criterion. Unfortunately that can often compromise the effectiveness with which they cover the network about which information is required. An example is provided by the experience of the UK Acid Waters Review Group [4] in the initial phase of its work during 1985. A nationwide trawl for the most relevant data on trends in pH and alkalinity produced large quantities of historical records. Of the 100 or so data sets received, however, very few described quality at points within the vulnerable headwaters where acidification was expected to show the most pronounced effects. Not surprisingly, the subsequent statistical analysis of the data produced very little information of direct relevance to UKAWRG's aims.

1.17 In a wider context, a similar conclusion has been reached by WRc [3] on the basis of the statistical analysis of many sets of data from multi-station river systems. We have found that, in the majority of cases, an appreciable proportion of the sampling points (typically about a quarter) contributed virtually no useful quality information that could not reliably be inferred from neighbouring sampling points. Again, therefore, there seem to be obvious opportunities for improving the effectiveness with which freshwater systems are routinely monitored.

Times

1.18 Because of practical constraints imposed by the working day of the sampling officer and the analytical laboratory, virtually all routine sampling data, whether for effluents or for freshwaters, is limited by a "time-window" restriction. Consequently the set of results for a particular river sampling point may fall within a span of only two or three hours. We have seen data for one Harmonised Monitoring site, for example, showing that over 95% of the weekly samples collected over a seven-year period had been taken at nine o'clock on a Thursday. So narrow a time window may be acceptable for some types of objective, but it will certainly not be for others.

1.19 Other more insidious problems arise when, as is likely, the time window does not remain rigidly constant but receives a discrete jolt every now and then through reorganisation of the sampling officer's schedule. Shold there be a diurnal effect in the river or effluent, or there be a change in the typical transit time of samples to the laboratory, the results subsequently appearing on the data base may show a bias relative to those gathered under the old regime. This is another unwelcome effect that emerged in the UKAWRG study. Figure 2 shows the long-term time trend found in pH at a sampling point on the River Derwent. No environmental reasons could be found for these two pronounced step changes in pH, and it was strongly suspected that they were due to changes in the sampling and/or analytical schedule — especially as similar steps were detected in the data supplied for other sampling points in the region.

Frequencies

1.20 Over the past 10 years, the majority of freshwater sampling points have been sampled no more frequently than monthly. The same has been true for sewage effluents. (In many cases, indeed, river locations and effluents of relatively little importance have been sampled as infrequently as quarterly.) Although monthly sampling can be adequate for some purposes, very misleading conclusions can be drawn if face-value comparisons of annual statements of quality between one year and another are made without an appreciation of the very large differences that can arise solely through chance sampling error. The numerical example provided earlier in paras 1.1 to 1.5 underlines this point.
A second and more tangible example of how the arbitrary selection of sampling frequencies can bear little relation to the declared objective concerns the Government's requirement for there to be a 50% reduction in loads of Red List substances to the North Sea between 1985 and 1995. Many of the undertakings responsible for demonstrating such reductions might typically sample major discharges and minor estuaries four times a year. Certainly monthly sampling would represent a big additional commitment over present levels. But given 12 estimates of load for 1985 and another 12 for 1995, we are limited to the following statements (on the basis of plausible assumptions about the type and size of the underlying variability):

- The true mean load would have to have reduced by a factor of 4.5 before the observed reduction would almost certainly be detected as being statistically significant.
- In those circumstances, the observed factor by which mean load had decreased could be anywhere between 2 and 10.
- If in truth there had been an exact halving in mean load, the chance that the observed reduction would be statistically significant is only 45%. So a case in which the Government's requirement had truly been achieved would be more likely than not to go unnoticed.

**Figure 2** Example of step changes in mean pH in a river (taken from the UKAWRG study)
Figure 3 Two examples of the results from WRc's AQUACHECK scheme

Histogram of mean results for BOD (mg/l)

```
                  No. of mean results 3 8 19 9 2 1
                     Class  2.35 3.05 3.75 4.45 5.15
                Boundaries  ->2.35 3.05 3.75 4.45 5.15
```

Number of laboratories reporting: 42
Overall mean: 3.28
Reference Value: 3.40 - WRc (spiked) value
Range of reported concentrations: 0.60 to 5.40

Histogram of mean results for AMMONIA (mg N/l) - Hard water sample

```
                  No. of mean results 2 1 3 20 35 12 7 0 1
                     Class  0.20 0.25 0.30 0.34 0.40 0.45 0.50 0.55 1.00
                Boundaries  ->0.20 0.25 0.30 0.34 0.40 0.45 0.50 0.55
```

Number of laboratories reporting: 81
Overall mean: 0.37
Reference Value: 0.36 - WRc (spiked) value
Range of reported concentrations: 0.02 to 1.00
Analytical error

1.22 The argument is sometimes heard that the natural variations in water or effluent quality are so great that the additional errors introduced by the chemical analysis of samples may be ignored. This may be so in some circumstances, but is certainly not in others. Compelling evidence of the distortions that can and still do arise through analytical error is provided by WRC’s AQUACHECK scheme, which has been in operation since 1985. The essence of the scheme is that samples of various types (“clean water”, “dirty water” and sludge) containing known concentrations of certain constituents are periodically distributed to over 100 participating laboratories in the UK and elsewhere. The resulting sets of estimated concentrations are then collated, analysed and reported to the participants by WRC.

1.23 Two examples relevant to the analysis of freshwater quality are provided in Figure 3. The histograms show the spread of BOD and ammonia results that were obtained for a recently distributed clean water test sample. From the upper histogram we see that the reported BOD values ran from 0.6 to 5.4 mg/l, with over half of the 42 laboratories that took part in this particular analysis producing a result outside the range (3.05–3.75) mg/l. For the 81 laboratories returning an ammonia result, the estimates reported in the lower histogram, even after omitting three very extreme responses, ran from 0.2 to 0.5 mg/l. Relative to the reference concentrations of 0.36, this represents an error range of nearly ± 50%.

1.24 If analytical errors of this order can be observed between laboratories that are all running their own internal AQC schemes, and indeed are sufficiently motivated to participate in AQUACHECK, the errors likely to have arisen in earlier years, when the procedures for controlling the variability of analytical results were far less well established, can perhaps be imagined. Dramatic biases may be introduced, for example, by changes in the analytical method. Such an instance involving a 10-year period of pH measurement is shown in Figure 4 (again borrowed from the UKAWRG study). We see that there was a mean drop of fully one pH unit following the change from manual to automatic measurement, and almost as marked an upward shift when the method was changed back to a modified manual procedure.

1.25 Bias is also likely to be introduced with a change of laboratories, an event that will typically have occurred several times during the 15-year lifetime of a water authority. What then happens, as in the examples of Figures 2 and 4, is that any genuine trends in quality over that period will be corrupted by an assortment of apparent changes that are simply artefacts introduced by the very process of sampling and analysis.

Measuring low pollutant levels

1.26 Further analytical difficulties arise when it is required to measure certain toxic substances which may be present only in very small concentrations in the sampled water. Such tasks often arise, for example, in connection with the Dangerous Substances Directive and with determinands on the Red List. In this context an important characteristic of the analytical procedure is the “limit of detection”, this being the minimum concentration that, if truly present in the water sample being analysed, will be detected with high probability by the analyst. As water quality standards become ever tighter, it is increasingly found that the achievable limits of detection are inadequate. What often happens in such cases is that the unknown actual concentration is reported as being the limit of detection itself. There is then a real danger that this small but biased value, when multiplied by a series of possibly very large river flows, generates a very substantial total load figure which is taken out of context and interpreted as though it were an unbiased estimate of load rather than an upper bound. This form of distorted reporting has led to one (apparently serious) suggestion that the best way to meet the Government’s 50% load reduction requirement would be to improve the analytical method so as to achieve a halving of the limit of detection.
Figure 4  Example of step changes in mean pH caused by changes in the method of pH measurement (taken from the UKAWRG study)
Judging compliance with standards

1.27 Ever since the late 1970s, issues relating to compliance with standards, and especially percentile standards, have been a source of much confusion in the water industry. Indeed, the emphasis placed on these matters seems often to have fostered the impression that the main or even sole reason for collecting quality data was for compliance purposes. This has distracted attention from other potentially more valuable uses of the data.

1.28 Compliance issues have caused problem for two reasons. One is that there are no ready parallels to the percentile standard in everyday life, where virtually all restrictions are of the straightforward “speed limit” type. Thus, the very idea that there can be a certain number or proportion of “allowed” exceedences of a limit has been found profoundly unsettling by many — not least because of the complications that it brings to questions of enforcement.

The burden of proof

1.29 The second aspect, however, has caused the greater difficulty. It derives from the phenomenon previously identified in para 1.1, namely the widespread tendency to regard sample estimates as being the true values in the underlying population. In reality, an observed per cent compliance with a particular standard may be higher or lower than the true level of compliance. Consequently the Regulator must decide what stance he is to adopt towards the burden of proof. There are three options:

- Benefit-of-doubt (that is, assume the monitored water or effluent is “innocent until proved guilty”);
- Fail-safe (the converse “guilty until proved innocent” stance); or
- Face-value (which is equivalent to ignoring the need to control the misclassification risks).

1.30 The power curves shown in Figure 5 illustrate these three stances and their implications in the context of monitoring a sewage effluent against a 95%ile standard on the basis of 60 random samples. For an effluent that was truly complying with the standard for exactly 95% of the time, we would on average expect three exceedences out of 60 samples (Curve “b”). But a fail-safe stance would demand zero failures in 60 samples (Curve “a”), whereas the benefit-of-doubt stance (Curve “c”) would allow up to six exceedences.

1.31 No one approach is right or wrong; each can be justified according to the context. Where, however, the sampling error arises because of imperfect measurement by the regulator, there is a strong prima facie case for adopting the benefit-of-doubt stance, in the manner required by the Courts. This approach is taken as axiomatic, indeed, in the statistical quality control methodology of BS 5700 recommended by the NRA’s Kinnersley report [5]. The contrasting face-value stance is seen most often in EC Directives, where a rule such as “at least 95% of samples must meet the standard” is commonly but erroneously taken as meaning that the standard is a 95%ile. The “95% of samples” rule is in fact stricter than that. With 60 samples, for example, Curve “b” shows that a water or effluent that was truly meeting a 95%ile standard would have more than a one in three risk of failing a “95% of samples” rule.

1.32 The greater the number of samples, the steeper the power curve and so the sharper the discrimination provided by the compliance test. This is illustrated by Figure 6, which shows the power curves for schemes to test compliance with an 80%ile standard based on sample sizes of 10, 20 and 40. The power curve provides a mechanism linking the sampling effort expended to the information gained, and so is the key to the effective design of a compliance-testing programme.

1.33 With absolute or “100%ile” standards, the position is rather different. There is no question now of taking either a fail-safe or a benefit-of-doubt stance: the only option is a face-value “100%
Power curves for 3 "pass/fail" rules

Figure 5  Illustration of the three possible stances towards sampling error in judging compliance with a 95%ile standard
Power curves for 3 "pass/fail" rules

Figure 6 Illustration of how the power of a compliance-testing scheme increases with sampling frequency
Appendix 6

of samples’” rule. Thus, no matter how many samples are taken, all must meet the standard if compliance is to be achieved. Of course, even when 100% of samples comply there does still remain the question of how much poorer than 100% the true compliance might be. Again, the level of protection improves with the number of samples. With 20 samples all meeting the standard, for example, we can be 95% confident only that the true level of compliance is no worse than 86%; but with as many as 100 samples all complying, the pessimistic lower bound on the true compliance figure rises to 97% [3]. As in the case of percentile standards, therefore, an understanding of how sampling error can be controlled by the choice of sampling frequency is the key to effective programme design.

Types of river quality standards

1.34 With statutory Water Quality Objectives due to be implemented by 1993, the situation at present regarding river quality standards is in a state of flux. The river classification system inherited by the NRA is an extension of the scheme developed by the NWC in the 1970s. All but one of the criteria are expressed as 95%ile limits (or 5%ile in the case of pH and dissolved oxygen); the exception is the suspended solids limit, which refers to average concentration. For waters designated under the terms of the Freshwater Fish Directive, there are also additional constraints on 90%ile and minimum dissolved oxygen concentrations.

Types of effluent standards

1.35 The present system for sewage effluent consent limits dates largely from 1985, and is based on 95%ile limits — that is, limits which are required to be met or bettered for at least 95% of the time. It had at the time been DoE’s intention to set absolute, or “upper-tier”, limits also, but that proposal was deferred indefinitely. In contrast, the consents for industrial discharges to freshwaters continued to specify absolute concentration limits on the various permitted pollutants, with no comparable move being made towards a percentile approach.

1.36 This perceived lack of evenhandedness historically between sewage and industrial effluents was a key point addressed in 1990 by the NRA’s Kinnersley Group. The Group’s report [5] proposes the setting of absolute concentration and flow limits on all types of consented discharge. It also recognises the merits of a dual-limits approach for certain types of effluent, whereby the consent includes:

- an absolute limit to protect against short-lived but gross pollution of the receiving watercourse; but also
- a percentile limit to control the more usual levels of pollutant in the effluent.

1.37 Although retaining the concept of a percentile-type limit, the Kinnersley report proposes a general replacement of 95%ile limits by 80%ile limits (in most cases, by a statistically “neutral” translation). For effluents whose quality variations contain a large random component, such a move would provide a more effective level of protection. The essence of the statistical argument is that, should there in truth be a deterioration in effluent quality, the chance of obtaining a compliance failure using an 80%ile-based scheme would be higher than the chance of failure using an equivalent 95%ile-based scheme (that is, the existing look-up table).

1.38 The Kinnersley report reaffirms the strength of the EQO-based approach to the setting of discharge limits, whereby the required effluent quality is dictated by the effluent’s impact on the receiving waters and the uses to which those waters are to be put. It furthermore recommends, in view of the complicated and uneven nature of much historical consenting practice, that there be a wide-ranging review of all numeric consents. This will be a major task, for there is no quick method of setting across-the-board percentile and absolute limits — a point particularly emphasised by Kinnersley. By the nature of the approach, each case must be considered individually, and the exercise will often call for the use of mass-balance quality modelling techniques.

1.39 Two major concerns will further complicate any such general review of consents:

- Setting absolute limits. Existing techniques primarily seek to model the variations in quality over the 5%ile to 95%ile range. It is open to question, therefore, how adequately they can capture the behaviour of more extreme concentrations in the effluent and the receiving water.
Allocating assimilative capacity. A wider issue is the question of how much of a receiving water’s assimilative capacity can be “used up” by the existing discharges, and how much should be reserved, either as a safety margin or to accommodate potential future dischargers. These issues have profound economic implications for both industry and the water companies, and they urgently need to be resolved in a manner that is seen as reasonable and workable by both regulated and regulator.

The Urban Waste Water Treatment Directive

1.40 The Kinnersley report did not comment in detail on the draft (as it then was) UWWT Directive; its view was that the Group’s recommendations were likely to lead to consent conditions at least as demanding as those eventually imposed by the Directive. More detailed comment could indeed have turned out to be irrelevant, as the sampling and compliance aspects of the Directive underwent radical change in the last few months before its adoption in 1991.

1.41 The table below shows that little common ground exists between the Directive’s requirements and the NRA proposals. The Directive requires 24-hour composite samples rather than spots; it imposes 95%ile rather than 80%ile limits; and these apply uniformly across a wide category of effluents, with no opportunity for relaxation where this would be justified under the EQO-based approach. However, the Directive does usefully indicate that alternative methods can be used by member states provided they can be demonstrated to be equivalent or more stringent. Thus, whilst it is unlikely that the UK will pursue the “alternative methods” option formally, there is nothing to prevent the NRA from imposing its preferred approach as an additional component of the consent in cases where it feels that the UWWT conditions in themselves

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<tr>
<td>Stance taken towards testing compliance with %ile limits</td>
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<td>(b) Limits are to be set according to the EQO approach.</td>
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<td>(c) In most cases, the 80%ile limits are to be set so as to effect a neutral translation from the previous 95%ile limits.</td>
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<td>(d) The limits shown here are those applying to the broad category of effluents produced by secondary treatment.</td>
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<td>(e) Extreme values due to unusual circumstances such as heavy rain may be excluded.</td>
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provide insufficient protection. In this way, the NRA would retain the main elements of the Kinnersley recommendations in the very situations in which they were likely to be of greatest environmental benefit.

Assessing water quality

1.42 As earlier paragraphs have indicated, assessments of freshwater and effluent quality based on routine compliance reports are subject to an uncomfortably large measure of uncertainty. One reason for this is that a pass/fail compliance assessment is a coarse screening process which does not make full use of the data. For example, the statement that an effluent has met its numerical consents for each of the last five years tells us merely that quality has consistently kept below a particular threshold. It gives no clue as to whether quality has improved or deteriorated over that time; for that, further statistical analysis is needed.

1.43 Despite this obvious need for better methods of quality assessment, the water industry has generally made poor progress in this area, partly because of its preoccupation with compliance-related issues, but mainly as a result of the DRIPS syndrome that we discussed in para 1.11. Over the past few years, however, a major catalyst for change has been the growth of microcomputers. The micro offers a more congenial working environment than is provided by most mainframe computers. Micro software packages, too, are tailored to the single, perhaps inexperienced user, and the availability of features such as built-in help screens, menus and colour graphics is now almost taken for granted. The term "user-friendly" may have become a cliche, but the sense that it conveys is nonetheless genuine.

1.44 Even when equipped with a micro, however, the water quality planner does have two problems still to overcome. First, he must find a means of transferring or "downloading" the required data from the existing mainframe computer archive into his micro; and secondly, he needs to acquire suitable software. The first is a problem experienced by the great majority of users, and so calls for company-wide solutions. In many organisations, in fact, the design of existing quality archives dates from the 1970s, and so modern database systems offer great potential for improvement. A good example of what can be achieved is WIS — a geographical information system developed by the Institute of Hydrology in collaboration with ICL. Using WIS, it is extremely easy to specify and extract a particular data set, and then to submit this to any desired GIS, graphical, statistical or modelling option. Integrated systems of this sort clearly point the way forward, and their widespread adoption will do much to encourage the more effective use of water quality data.

1.45 The other requirement is appropriate software. An obvious choice might seem to be one of the many excellent statistical packages that are available for the micro. These are certainly ideal for the statistically inclined but less so for the non-specialist, who can easily be overwhelmed by the sheer variety of statistical techniques on offer. At the other extreme, spreadsheets offer a useful way of manipulating data and producing simple plots; but they can become restrictive when more substantial statistical routines and tests are called for.

1.46 The most satisfactory solution, we believe, is to use software that has been developed expressly with the water quality planner's requirements in mind. The NRA has taken a useful initiative in this area by funding such products as the catchment quality simulation model SIMCAT, and Wrc's ZEBRA and LAPWING packages. Another product that has been tailored specifically to common water industry objectives is Wrc's AARDVARK package for trend detection and general data exploration. Figures 7 and 8 give some idea of the variety of functions provided by AARDVARK. As these indicate, the emphasis throughout AARDVARK is on graphical presentation, with statistical calculations and tests kept in the background and invoked automatically only where relevant. Within a year of its introduction, AARDVARK was well established both across the NRA and in the Water Companies, and its popularity is a good indication of the great demand that exists for user-oriented products of this sort.
Figure 7  Illustration of the “detailed summary” and “year-on-year” functions provided by the AARDVARK package

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**RIVER RIBBLE AT SAMLESBURY PGS**

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Figure 8  Illustration of the "time series" and "histogram" functions provided by the AARDVARK package

![Image of the "time series" and "histogram" functions provided by the AARDVARK package](image-url)
Improving the information available on freshwater and effluent quality: conclusions and recommendations

Sampling programme design

1.47 Routine water quality sampling programmes in the past have been driven almost entirely by historical inertia. As a consequence, the spatial network of freshwater sampling points has remained largely static. Sites that are contributing little or no useful information are seldom dropped, and this limits the opportunities to introduce new sites where better, more localised information is needed. The argument that continuity is essential in order to preserve the historical record would be more convincing if there were more evidence that those historical records did subsequently get used constructively.

1.48 A similarly passive temporal pattern has persisted over the years. Familiar annual sampling frequencies such as 4, 6, 12 and 24 have routinely been adopted, often with little regard for the information content of the data that they generate.

1.49 There does, however, now seem to be an increasing resolve to plan future water quality sampling programmes more effectively. On the NRA side, for example, there is a general awareness of the shortcomings of the water industry's quinquennial river quality surveys in 1975, 1980 and 1985. Not only did the classification rules differ across the 110 water authorities in any one survey; the rules also changed in many cases from one survey to the next even within the one authority. Here and in other areas the NRA have taken a number of positive actions to improve matters, both on river sampling in general and on the conduct of the 1990 river quality survey in particular.

Definition of sampling programme

1.50 To encourage a sustained improvement in the planning of sampling programmes, we recommend that all programmes should include the following documentation:

- a clear, quantitative definition of the objectives — including a statement of the parameters to be estimated by the programme and the required levels of precision and confidence;
- an unambiguous set of protocols governing all the practical aspects of sampling;
- a detailed specification of the methods by which the generated data is to be interpreted so as to meet the stated objectives; and
- a specification of the nature and frequency of the reporting mechanisms in order to ensure that the right information reaches the right parts of the organisation at the right times.

Resources for data handling and interpretation

1.51 Though there are isolated exceptions, it is evident that the purposeful interpretation of routinely collected water quality data has generally received far too little attention over the past 15 years. A very common plea in the days of the water authorities was: "We have not had the time to look at the data". The complaint continues to be heard on both sides of the water industry, and indeed from central government agencies too.

1.52 The solution to this deep-seated problem calls for a radical change in the way that sampling programmes are planned and resourced. It must become second nature for a realistic allowance to be made for the manpower and software resources needed for all necessary analysis and interpretation of the data that the programme will generate. This would include a recognition of the effort needed on the unsung but vital "housekeeping" aspects of data entry, data validation, and maintenance of the data archiving and retrieval system.

Recognising sampling error

1.53 There is still too little general appreciation of the uncertainty inevitably surrounding the results from any sampling programme. To encourage an awareness of the existence and
Appendix 6

consequences of sampling error, we recommend that, in all routine statements about water or effluent quality, automatic provision is made for each estimate to be accompanied by an appropriate confidence interval. For example:

- Based on 24 samples, the estimated 95%ile ammonia concentration during 1989 was 0.85 mg/l, with 90% confidence limits of 0.54 and 1.62 mg/l.
- Six out of 20 sewage effluent BOD values exceeded the numerical consent, and so the estimated compliance is 70%, with 90% confidence limits of 49% and 86%.

Controlling analytical error

1.54 The results obtained from WRc's AQUACHECK scheme and other inter-comparison exercises bear witness to the continuing importance of ensuring that analytical errors are controlled to tolerable levels. This is especially vital in the increasingly common circumstances in which very low concentrations of highly toxic pollutants are of concern. We recommend, accordingly, that appropriate quality control procedures are used by all laboratories involved in sample analysis to ensure that the overall accuracy figures are within the limits stipulated at the time of designing the programme.

Combating DRIPS

1.55 Over the past 15 years, the water industry has generally been poorly served by its computer systems — both hardware and software. The process by which water quality officers extracted data from their mainframe computer archives tended to be slow and cumbersome; and when they managed to surmount that obstacle, very little appropriate software was available that would enable them to look constructively at their data.

1.56 This state of affairs should not be allowed to persist. Almost always, water quality data that accumulates as part of a routine sampling programme will be of use not only in achieving the originally planned (and documented) objectives, but also more widely. To encourage this more general use of the data, attention should be paid to:

- improving the flexibility and accessibility of data archiving and retrieval systems; and
- expanding the availability and use of relevant data analysis and interpretation software.

References

APPENDIX 7

POLLUTION CHARGES IN GERMANY

1. The German charging system was introduced (in the former Federal Republic) in 1976 under the Wastewater Charges Act (Abwasserabgabengesetz) and the charges were first levied in 1981. Responsibility for various aspects of the charging system and the broader area of water quality is split between the federal government and the states (Länder) (see box A.1).

2. The Wastewater Charges Act requires that most direct dischargers into the aquatic environment pay charges. (Rain water discharges from areas up to 3 ha, for instance, are exempt.) The charge is levied by the Länder on all industries and municipalities which discharge directly into lakes, rivers, the sea or groundwater used for drinking. Spills and diffuse sources are not charged under the scheme.

3. Those discharging into sewers do not pay the charge directly. However, sewerage undertakers are liable to pay the charge for their own effluent discharges to water and so the cost is passed on in the charge levied for the use of the sewerage system. Charges for discharges to sewers vary but tend to include conveyance and treatment charges (as in the UK) as well as a contribution to the cost of the charge levied under the Wastewater Charges Act.

4. The formula used to calculate the charge is set at Federal level and is the same for all Länder. The pollutants covered by the system are:
   - chemical oxygen demand (COD);
   - phosphorus;
   - nitrogen;
   - halogenated organic compounds as adsorbable on activated carbon (AOX);
   - several metals and their compounds (Mercury, Cadmium, Chromium, nickel, lead, copper);
   - substances toxic to fish.

5. A unit of each of these pollutants is charged at the same rate but the units vary with each pollutant. For example, for COD the unit of pollution is 50kg, for mercury the unit is 20g and for copper, 1000g. Threshold values are given in the waste water charge law, both in terms of minimum concentration and total annual load which both must be exceeded before charges are levied. The threshold values for COD for example, are 20mg/l and 250kg/annum. The law also lays down the analytical methods to be used.

6. The scheme was implemented gradually. There was a five year period between the passing of the enabling legislation and the introduction of charges in 1981. The charge was initially set at a level of DM12/unit. This rose in annual steps to DM 40/unit in 1986. In 1990, the level was revised again, to DM50/unit from 1 January 1991 and will increase in biennial steps to DM90/unit by 1 January 1999.

7. A number of features of the scheme are designed to enhance the incentive to dischargers to improve the quality of their effluent. For example, if a discharger submits plans for the installation of an effluent treatment plant the reduction in the charge that this investment will produce is granted for a period of three years prior to the date of commissioning the new plant, provided that the reduction in load is at least 20%. If the plant is not installed or fails to meet its target performance then the discharger must pay back any unjustified reductions. Dischargers also receive 75% reductions in their charges if their treatment plants meet federally defined effluent standards. These latter reductions are now time limited falling to 40% after 4 years and 20% after a further 4 years. However, if the federal standards are subsequently tightened and the
BOX A.1 THE GERMAN CHARGING SYSTEM – LEGISLATIVE FRAMEWORK AND RESPONSIBLE AUTHORITIES

Germany has a federal system of government with many responsibilities exercised by the states (the Länder). Responsibility for environmental protection is split between the levels of Government with the Länder in the lead. It is not always possible to generalise about the practices from Land to Land.

In the areas of water management (except drinking water quality legislation) and nature protection, the Federal Government passes framework laws which require the agreement of the upper house (where Länder representatives sit). The Länder then implement the law, passing Länder laws within the framework of the Federal Law.

The federal authorities are responsible for:

* promulgating technology-based emission standards for industries and municipalities;
* determining the pollutants on which the charge is based;
* setting the charge level.

The Länder are responsible for the implementation and enforcement of water quality goals and the charges.

The two main German laws concerning the management and protection of water resources are the Federal Water Resources Act (1957, last amended in 1986) and The Federal Wastewater Charging Act (1976, last amended in 1990). These two laws and the resultant Regulations form the basis of German practice in water pollution control and conservation of water resources.

The responsible authorities for various aspects of these laws vary between the Länder. Under the Federal Water Resources Act, licences or permits are required for the right to use ground and surface water i.e. for the impounding of, abstractions from and discharges into surface and ground water. The responsible authority is specified by the Land and in practice it is usually the Regional State Authorities.

BOX A.2 USE OF THE REVENUE

The Act specifies seven measures which may be funded by the revenue derived from the charges.

i. The construction of waste water treatment plants;

ii. The construction of run-off retention basins and run-off purification facilities;

iii. The construction of protection channels around lakes and along dams, sea-shores and of main connecting sewers thus permitting the construction of jointly-owned treatment facilities;

iv. The construction of plants for the disposal of sewage sludge;

v. Measures for monitoring, improving and maintaining the quality of waterbodies;

vi. Research and development on processes and techniques for improving water quality;

vii. Provision of basic and further training for operations staff on facilities designed to improve and maintain water quality.
effluent meets the new standards, the charges are again reduced by 75%. This is intended to encourage further development of improved treatment technology.

8. The revenue raised from the charging scheme is collected by the Länder who are required under the Act to use the funds to improve or maintain the quality of the aquatic environment (see box A.2). This includes contributing towards the cost of pollution control measures undertaken both by municipalities and by private industry and the costs of administering the system. For example, funds can be applied to the provision of new or upgraded sewage works for towns and villages. The Act specifies the measures which may be funded by the revenue derived from the charges.

9. The charges are based on discharge permit values but on certain conditions may be based on a declaration by the discharger. The Länder may delegate collection of the charges to local authorities.

10. Monitoring and enforcement are the responsibility of the Länder and arrangements vary between them. They are carried out at local or regional level depending on the importance of the discharge.

11. Direct discharges are self-monitored (that is the dischargers themselves collect and analyse the samples, sending the results to the regulatory authority), with compliance samples (samples collected and analysed by the regulatory authority) taken at random intervals. The latter are used to ensure that the consent is met and, if necessary, for prosecution and that the self-monitoring is reliable. For compliance purposes, five samples are taken in a rolling programme. If one of the samples exceeds the permitted or declared value by 100% or more, the units are increased by half of the percentage excess. If more than one sample exceeds the permitted or declared level by 100% or more, the units are increased by the full amount of the percentage excess of the highest level found. To attain a reduction in units, the discharger may notify the authorities that he will observe lower values than those stipulated in the permit. This is then used for calculating the charge.

12. The frequency of monitoring depends on the size and potential risk of the polluting load; self-monitoring may take place as little as once a quarter or, for major discharges, as often as

**BOX A.3 THE GERMAN PERMIT SCHEME**

Under the Water Resources Act, a permit is required for all discharges into the water environment. The permits specify the maximum quantity and the required quality of the effluent. Minimum effluent standards are laid down in Federal Regulations for different branches of industry, including domestic waste waters, which are used by the Länder water authorities as minimum standards. The standards are based on generally available technology for sanitary parameters and best available technology for hazardous parameters. Stricter standards can be set but these have to be justified.

The Federal Regulations which set the effluent standards can be amended. (For example, in 1990 standards for phosphorus were added to the domestic waste water regulations.) New plants are expected to comply with new standards but reviews of existing permits are at the discretion of the local licensing authorities.

The discharger has to carry out self-monitoring, the frequency of which is laid down in the permit. For example, the permit of one plant treating approximately 150 Ml/d specifies that fifty-two 24 hour proportional samples have to be taken. Permit compliance monitoring by the authorities varies up to 12 times a year depending on the size of the plant and the individual Land. Large chemical plants are sampled up to 30-40 times a year.
Appendix 7

every day. Compliance monitoring is much less frequent — up to 12 times a year for domestic sewage and up to 30–40 times a year for large chemical plants (see 'the German permit scheme', box A.3).

13. Monitoring for compliance with the consent and for charging are usually combined. If the consent is exceeded, dischargers may be taken to court. Compliance samples are split three ways — one for the discharger, one for the authorities and one for storage.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADAS</td>
<td>Agricultural Development and Advisory Service</td>
</tr>
<tr>
<td>AFRC</td>
<td>Agricultural and Food Research Council</td>
</tr>
<tr>
<td>ASPT</td>
<td>Average score per taxon</td>
</tr>
<tr>
<td>BATNEEC</td>
<td>Best Available Techniques Not Entailing Excessive Cost</td>
</tr>
<tr>
<td>BGS</td>
<td>British Geological Survey</td>
</tr>
<tr>
<td>BMWP</td>
<td>Biological Monitoring Working Party</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>BOD (ATU)</td>
<td>Biochemical Oxygen Demand (Allylthiourea)</td>
</tr>
<tr>
<td>BPEO</td>
<td>Best practicable environmental option</td>
</tr>
<tr>
<td>BW</td>
<td>British Waterways</td>
</tr>
<tr>
<td>CBI</td>
<td>Confederation of British Industry</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>COPA</td>
<td>Control of Pollution Act</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of the Environment</td>
</tr>
<tr>
<td>DOE(NI)</td>
<td>Department of the Environment (Northern Ireland)</td>
</tr>
<tr>
<td>EC</td>
<td>European Community</td>
</tr>
<tr>
<td>EDU</td>
<td>Environment Data Unit</td>
</tr>
<tr>
<td>EIFAC</td>
<td>European Inland Fisheries Advisory Committee</td>
</tr>
<tr>
<td>EQI</td>
<td>Ecological Quality Index</td>
</tr>
<tr>
<td>EQO</td>
<td>Environmental Quality Objective</td>
</tr>
<tr>
<td>EQS</td>
<td>Environmental Quality Standard</td>
</tr>
<tr>
<td>ERL</td>
<td>Environmental Resources Limited</td>
</tr>
<tr>
<td>FEPA</td>
<td>Food and Environment Protection Act 1985</td>
</tr>
<tr>
<td>HAZCHEM</td>
<td>Hazardous chemical</td>
</tr>
<tr>
<td>HMIP</td>
<td>Her Majesty's Inspectorate of Pollution</td>
</tr>
<tr>
<td>HMIPI</td>
<td>Her Majesty's Industrial Pollution Inspectorate</td>
</tr>
<tr>
<td>HMS</td>
<td>Harmonised Monitoring Scheme</td>
</tr>
<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
</tr>
<tr>
<td>IOH</td>
<td>Institute of Hydrology</td>
</tr>
<tr>
<td>LCP</td>
<td>Large combustion plant</td>
</tr>
<tr>
<td>MAC</td>
<td>Maximum Admissible Concentration</td>
</tr>
<tr>
<td>NCC</td>
<td>Nature Conservancy Council</td>
</tr>
<tr>
<td>NERC</td>
<td>Natural Environment Research Council</td>
</tr>
<tr>
<td>NOx</td>
<td>Oxides of nitrogen</td>
</tr>
<tr>
<td>NRA</td>
<td>National Rivers Authority</td>
</tr>
<tr>
<td>NSA</td>
<td>Nitrate Sensitive Areas</td>
</tr>
<tr>
<td>NWC</td>
<td>National Water Council</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>OFWAT</td>
<td>Office of Water Services</td>
</tr>
<tr>
<td>PCB</td>
<td>Polychlorinated biphenyl</td>
</tr>
<tr>
<td>PCP</td>
<td>Pentachlorophenol</td>
</tr>
<tr>
<td>PHLS</td>
<td>Public Health Laboratory Service</td>
</tr>
<tr>
<td>RCEP</td>
<td>Royal Commission on Environmental Pollution</td>
</tr>
<tr>
<td>RIVPACS</td>
<td>River Invertebrate Prediction and Classification System</td>
</tr>
<tr>
<td>RPA</td>
<td>River Purification Authority</td>
</tr>
<tr>
<td>RPB</td>
<td>River Purification Board</td>
</tr>
<tr>
<td>SDD</td>
<td>Scottish Development Department</td>
</tr>
<tr>
<td>SO2</td>
<td>Sulphur dioxide</td>
</tr>
<tr>
<td>SOEnD</td>
<td>Scottish Office Environment Department</td>
</tr>
<tr>
<td>SS</td>
<td>Suspended Solids</td>
</tr>
<tr>
<td>SSSI</td>
<td>Site of Special Scientific Interest</td>
</tr>
<tr>
<td>STW</td>
<td>Sewage treatment works</td>
</tr>
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</table>
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>SWAP</td>
<td>Surface Waters Acidification Project</td>
</tr>
<tr>
<td>SWQO</td>
<td>Statutory Water Quality Objective</td>
</tr>
<tr>
<td>TOC</td>
<td>Total organic carbon</td>
</tr>
<tr>
<td>UKAWRG</td>
<td>United Kingdom Acid Waters Review Group</td>
</tr>
<tr>
<td>UKRGAR</td>
<td>United Kingdom Review Group on Acid Rain</td>
</tr>
<tr>
<td>UN-ECE</td>
<td>United Nations-Economic Commission for Europe</td>
</tr>
<tr>
<td>WA</td>
<td>Water Authority</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>WQO</td>
<td>Water quality objective</td>
</tr>
<tr>
<td>WRc</td>
<td>Water Research Centre</td>
</tr>
<tr>
<td>WSC</td>
<td>Water Services Company</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>Of organisms, able to grow in the absence of oxygen.</td>
</tr>
<tr>
<td>Anions</td>
<td>Negatively-charged atoms or groups of atoms, for example, chloride ion ($\text{Cl}^-$), hydroxyl ion ($\text{OH}^-$), sulphate ion ($\text{SO}_4^{2-}$).</td>
</tr>
<tr>
<td>Anoxic</td>
<td>Of an environment, devoid of oxygen.</td>
</tr>
<tr>
<td>Anthropogenic</td>
<td>The consequence of human activities.</td>
</tr>
<tr>
<td>Aquifer</td>
<td>Layers of underground porous rock which contain water.</td>
</tr>
<tr>
<td>Benthic</td>
<td>Pertaining to the bed of a waterbody.</td>
</tr>
<tr>
<td>Billion</td>
<td>One thousand million.</td>
</tr>
<tr>
<td>Biota</td>
<td>Living organisms.</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand</td>
<td>Measure of the amount of oxygen consumed in a standard volume of water, usually by organic pollution. One of the three standard sanitary determinands widely used in characterising effluent quality. The simple BOD value can be misleading because much more oxygen is taken up by ammonia in the test than in the natural state. This effect is suppressed by adding a chemical, allylthiourea (ATU), to the sample of water taken for testing; hence BOD(ATU) (see box 3.1).</td>
</tr>
<tr>
<td>(BOD and BOD(ATU))</td>
<td></td>
</tr>
<tr>
<td>Catchment</td>
<td>Total area from which rainfall flows into a given waterbody such as a river.</td>
</tr>
<tr>
<td>Cations</td>
<td>Positively-charged atoms or groups of atoms, for example, calcium ion ($\text{Ca}^{2+}$), sodium ion ($\text{Na}^+$), ammonium ion ($\text{NH}_4^+$).</td>
</tr>
<tr>
<td>Chemical Oxygen Demand</td>
<td>Measure of the amount of oxygen consumed by dissolved and suspended matter when a sample is treated with a chemical oxidant under defined conditions (see box 3.1).</td>
</tr>
<tr>
<td>(COD)</td>
<td></td>
</tr>
<tr>
<td>Chironomid</td>
<td>A family of midges.</td>
</tr>
<tr>
<td>Controlled waters</td>
<td>All rivers, canals, lakes, groundwaters, estuaries, and coastal waters (within three nautical miles of the shore).</td>
</tr>
<tr>
<td>Critical load</td>
<td>The maximum pollutant load that a given ecosystem can tolerate without suffering adverse effects.</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>Some species of oxygenic photosynthetic bacteria which grow very rapidly in nutrient-rich waters and can produce scums and toxins; commonly called blue-green algae (see box 6.4).</td>
</tr>
<tr>
<td>Cyprinid fish</td>
<td>Fish of the carp family to which many UK freshwater fish belong, for example, dace, minnow and roach.</td>
</tr>
<tr>
<td>Determinand</td>
<td>Any substance or property of a water sample whose value is measured.</td>
</tr>
</tbody>
</table>
Glossary

Diatoms
Microscopic, generally single-celled algae with silica-containing cell walls.

Discharge consent
A statutory document permitting discharge of an effluent, subject to conditions and limitations, to a controlled water.

Ecosystem
Ecological system such as a soil, forest or lake, defined by the types of organisms found in it and their interactions.

Epilimnion
Warmer, less dense, oxygen-rich upper water layer above the thermocline in deep lakes.

Eutrophic
Of a waterbody, rich in nutrients.

Eutrophication
Process of nutrient enrichment.

Groundwater
Underground water, often in aquifers.

Heavy metals
Metals of moderate to high atomic number, for example, copper, zinc, nickel, lead.

Hypertrophic
Of a waterbody, in an extreme state of nutrient enrichment.

Hypolimnion
The layer of cold, dense water between the thermocline and the bottom of a deep lake.

Invertebrates
Animals which have no internal skeleton (literally no backbone).

Iron pyrites
Sulphide of iron (FeS₂).

Kick sampling
Sampling the material from the bed of the watercourse by disturbing (or kicking) it to suspend material which is then collected in a net with a specified mesh size, usually about 1 millimetre.

Leachate
Liquid that has percolated through or out of a substrate.

Leptospirosis
A disease of animals or man caused by bacteria of the genus *Leptospira*, resulting in malaise, fever and jaundice.

Macro-invertebrates
Invertebrate animals of sufficient size to be retained in a net with a specified mesh size, usually about 1 millimetre.

Macrophytes
Plants which can be seen with the naked eye.

Mesotrophic
Of a waterbody, moderately enriched by nutrients.

Microbe/Micro-organism
A microscopic organism, such as a bacterium, virus, single-celled alga, yeast or mould.

Molluscicide
A substance used to kill molluscs, such as slugs, snails, cockles, mussels.

Mutagenic
Capable of causing a change in the amount or structure of genetic material (DNA) resulting in a heritable change in the characteristics of the cell or organism.
<table>
<thead>
<tr>
<th>Glossary</th>
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<tbody>
<tr>
<td><strong>Nutrient</strong></td>
</tr>
<tr>
<td><strong>Oligochaete</strong></td>
</tr>
<tr>
<td><strong>Oligotrophic</strong></td>
</tr>
<tr>
<td><strong>Organochlorine</strong></td>
</tr>
<tr>
<td><strong>pH</strong></td>
</tr>
<tr>
<td><strong>Pathogen</strong></td>
</tr>
<tr>
<td><strong>Pentachlorophenol (PCP)</strong></td>
</tr>
<tr>
<td><strong>95 percentile</strong></td>
</tr>
<tr>
<td><strong>Permeability</strong></td>
</tr>
<tr>
<td><strong>Phytoplankton</strong></td>
</tr>
<tr>
<td><strong>Plaque-forming units</strong></td>
</tr>
<tr>
<td><strong>Polychlorinated biphenyls (PCBs)</strong></td>
</tr>
<tr>
<td><strong>Population equivalent</strong></td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
</tr>
<tr>
<td><strong>River Invertebrate Prediction and Classification System (RIVPACS)</strong></td>
</tr>
<tr>
<td><strong>Saprobic</strong></td>
</tr>
<tr>
<td><strong>Salmonid fish</strong></td>
</tr>
<tr>
<td><strong>Silica</strong></td>
</tr>
</tbody>
</table>
### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site of Special Scientific Interest (SSSI)</strong></td>
<td>An area of land designated under the Wildlife and Countryside Act 1981 as of special interest because of any of its flora, fauna, or geological or physiographical features.</td>
</tr>
<tr>
<td><strong>Slurry</strong></td>
<td>Animal waste in a liquid form.</td>
</tr>
<tr>
<td><strong>Soakaway</strong></td>
<td>A depression into which water percolates.</td>
</tr>
<tr>
<td><strong>Spirochaetes</strong></td>
<td>Group of slender, helically coiled bacteria with flexible bodies and no rigid cell walls. They include free-living commensal and parasitic forms including some human and animal pathogens such as <em>Leptospira interrogans</em> which causes leptospirosis.</td>
</tr>
<tr>
<td><strong>Suspended solids</strong></td>
<td>Solids removed by filtration or centrifugation under specified conditions. One of the standard determinands widely used in characterising effluent quality.</td>
</tr>
<tr>
<td><strong>Taxon (taxa pl.)</strong></td>
<td>Any defined unit (such as a species, genus or family) used in the classification of living organisms.</td>
</tr>
<tr>
<td><strong>Teratogenic</strong></td>
<td>Capable of causing abnormal development of the embryo and congenital malformations.</td>
</tr>
<tr>
<td><strong>Thermal stratification</strong></td>
<td>Formation of layers (epilimnion, metalimnion and hypolimnion) of different temperature in a still, deep lake due to the differential heating of water. The epilimnion and hypolimnion are separated by the metalimnion, an intermediate region in which the thermocline is steepest.</td>
</tr>
<tr>
<td><strong>Thermocline</strong></td>
<td>A layer of water in which the temperature changes rapidly with increasing depth between the epilimnion and hypolimnion in lakes.</td>
</tr>
<tr>
<td><strong>Total organic carbon (TOC)</strong></td>
<td>The concentration of carbon present in the organic matter which is dissolved or suspended in water.</td>
</tr>
<tr>
<td><strong>Trade effluent</strong></td>
<td>Any liquid (including any suspended matter) which is wholly or partly produced in the course of any trade or industry but excluding sewage.</td>
</tr>
<tr>
<td><strong>Trophic level</strong></td>
<td>Broad class of organisms within an ecosystem characterised by mode of food supply. Thus, green plants (primary producers) belong to the first trophic level because they manufacture their own food.</td>
</tr>
<tr>
<td><strong>Water column</strong></td>
<td>Vertical column of water from the surface to the bottom of a waterbody.</td>
</tr>
<tr>
<td><strong>Water Quality Objective (WQO)</strong></td>
<td>The quality that a body of water is to achieve, usually defined in terms of suitability for specified uses.</td>
</tr>
<tr>
<td><strong>Water Quality Standard (WQS)</strong></td>
<td>The concentration of a substance in a water sample which must not be exceeded if a specified WQO is to be achieved.</td>
</tr>
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</table>
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18. Ibid.
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33. Ibid.
37. Dore et al., op. cit.
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10. FOE written evidence.
11. HMIP. Op cit.
12. National Water Council, op cit, paragraph 7(i): ‘Existing consents to discharges of effluent to streams are not always rationally related to environmental quality objectives—some are unnecessarily stringent, others not stringent enough.’
15. Ibid, paragraph 7(ii): ‘A number of existing consents are not consistent with what is currently practicable with existing treatment plant or with the funds available to produce improvement within the immediately foreseeable future.’
17. In which we commented that ‘the problem will not be solved unless, as emphasised in the Report, more public money is invested. We think therefore that the Government ought, in deploying limited resources, to give a very high priority to the substantial increase in public spending on sewerage and sewage treatment recommended by the Working Party’.
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Figure 1.5 River quality in England and Wales 1990

RIVER QUALITY 1990
ACCORDING TO THE NWC CLASSIFICATION SCHEME
Scale 1:750,000 or about 12 mules to 1 inch

Kilometres

NATIONAL REGIONS
RIVER FLOW RANGE
Cubic metres per second

2.5

20

40

60

RIVER AND CANAL QUALITY

1

2

3

4

FAIR
POOR
BAD

ESTUARY QUALITY
GOOD
FAIR
POOR
BAD

RIVER/ESTUARY BOUNDARY
NRA REGIONAL BOUNDARIES
DEVELOPED AREAS

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