ENVIRONMENTAL ISSUES SERIES

Aquatic eutrophication in England and Wales

A proposed management strategy

Consultative Report

ENVIRONMENT AGENCY

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December 1998

The cover picture shows shoreline accumulation of filamentous algae.

FOREWORD

Nutrient enrichment and eutrophication have an increasing political, scientific and public profile at national and international level. The need to tackle nutrient enrichment, in order to reduce the threats to biodiversity and freshwater fisheries, was one of ten key issues highlighted in the Agency's recent report on the State of Fresh Waters in England and Wales.

The Agency and its predecessors have been active in the management and control of eutrophication for many years. This involvement has been at the local level, for example in the Norfolk Broads and many still water bodies affected by blue-green algal problems, and nationally and internationally by contributing to the development and implementation of legislation. Such experience has informed the development of proposals for a national strategy for managing aquatic eutrophication in England and Wales. Work on our strategy has now reached the stage where we wish to seek the views of interested individuals and organisations on our proposed future approach to this issue.

A key element of our proposals is a partnership approach to the management of eutrophication. This is primarily because the control of nutrient inputs, particularly from diffuse sources, is generally beyond the remit of any one regulatory body. It is therefore important that all key stakeholders acknowledge the need to tackle eutrophication as an issue and that we work together to determine the best approach.

Another important principle is the need for catchment based action, within the context of a national framework for management. The intention is to ensure that actions, to assess and resolve problems at the local level, are pursued in the light of the best available tools, techniques and practices.

Our initial discussions with Government departments (in particular DETR and MAFF) and other UK regulators have been encouraging, but a wider and more detailed consultation is required, in particular with those whose activities influence eutrophication and those who are affected by its impacts.

Once we have considered the responses to this consultation we will determine, in more detail, the way forward. This will involve, amongst other things, determining priority sites for action and further developing links with other partners in the management of aquatic eutrophication. We look forward to receiving your views.

DR PAUL LEINSTER
Director of Environmental Protection

SUMMARY

The Environment Agency of England and Wales (the Agency) has adopted an integrated approach to the management of the environment, as set out in its Environmental Strategy (Environment Agency, 1997). This approach has highlighted the need for specific strategies to address the environmental impacts and risks associated with some issues. These include aquatic eutrophication, where human activities cause water to be enriched by nutrients, giving rise to adverse effects on both the ecology and the legitimate uses of water. This document sets out proposals for a strategy to manage aquatic eutrophication in England and Wales.

The importance of eutrophication as a national water quality issue was highlighted in a recent report on the state of the freshwater environment in England and Wales (Environment Agency, 1998a). This identified nutrient enrichment as one of ten priority issues requiring attention in order to achieve a more sustainable balance between the needs of society and the health of freshwater ecosystems. Its impacts are most evident in, but not exclusively confined to, lakes, reservoirs and slow-flowing rivers in central and south-east England. There is also concern about the effects in some waters of high conservation status. The problems and risks posed by eutrophication, together with the nature and complexities of the issue, are considered sufficient to warrant a strategy in this area. Its proposed key elements are:

- the promotion of a partnership approach to eutrophication management, at both local and national level, since solutions are generally beyond the remit of any one regulatory body or other party;
- the adoption of a range of regulatory and other mechanisms (voluntary, collaborative, educational and economic), by the Agency and others, to reduce nutrient inputs to environmental waters;
- a review of the arrangements for measuring the extent of eutrophication in different types of waters (standing fresh waters, running fresh waters, estuaries and coastal waters), and the impacts of discharges and land use on water quality;
- the prioritisation of waters for management action on the basis of specified criteria. Initial proposed priorities are: waters where there are statutory requirements; or where water uses are adversely affected; or where special conservation interest is at risk; or where benefits can be delivered or deterioration prevented, with adequate confidence, at reasonable cost;
- the adoption of interim targets for eutrophication control in fresh waters, and the application of specific statutory and/or international commitments in relation to saline waters;
- the management of eutrophication at site-specific level through the development of catchment-based action plans, with community involvement where appropriate, within the context of the national framework;
- the promotion of a wider understanding of the nature and significance of aquatic eutrophication; and
- a programme of research and development to improve scientific understanding of the eutrophication process.

Specific issues within the proposed management strategy, on which we are seeking the views of consultees, are sign posted throughout the document, and are summarised in Section 10 (Consultation Arrangements).

Following this consultation, the Agency intends to liaise with other key organisations in drawing up an implementation plan, comprising a national framework for managing eutrophication. Delivery of the plan will be influenced strongly by the relevant statutory requirements and international commitments and, beyond these initiatives, by the degree of consensus on appropriate action.

CONTENTS

1. INTRODUCTION

1.1 Purpose of this document

The purpose of this consultation document is to:

- describe the causes and impacts of aquatic eutrophication;
- explain the role of the Agency in managing the environment and eutrophication in particular;
- establish the need for a national strategy on eutrophication;
- outline the key features of the Agency's proposed strategy for assessing and managing eutrophication in England and Wales; and
- **seek the views of interested parties on the proposed approach.**

1.2 Background

The impacts of cultural eutrophication, where environmental waters are enriched by nutrients deriving from human activities, have for many years posed significant water quality problems in countries across the world. In general these problems have worsened in recent decades. The nature and extent of such problems vary considerably, across both time and space, but encompass adverse effects on both the ecology and the legitimate uses of waters.

In England and Wales, eutrophication as a water quality issue has had a high profile since the late-1980s, when the widespread occurrence of blue-green algal blooms in standing and slow-flowing fresh waters gave rise to considerable interest and concern by the public, the media and within the water industry. The attention of the industry and regulatory bodies was further heightened by the introduction in 1991 of the European Community (EC) Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) which requires regular reviews of eutrophication in environmental waters and the control of nutrient inputs from sewage treatment works (STWs) discharging to affected waters.

A significant body of work on assessing and managing the impacts of eutrophication was undertaken by the National Rivers Authority (NRA), one of the organisations which in 1996 was subsumed within the Environment Agency of England and Wales (the Agency). This work has been taken forward by the Agency, which has a wide range of duties and powers relating to environmental management, its fundamental objective being to help achieve sustainable development. The Agency's Environmental Strategy for the Millennium and Beyond (Environment Agency, 1997) outlines nine main environmental priority areas which the Agency intends to address and proposes a range of actions on each. Among these is a commitment to control eutrophication, where feasible, in order to enhance biodiversity.

The importance of nutrient enrichment as a national water quality issue was highlighted in a recent report on the state of the freshwater environment in England and Wales (Environment Agency, 1998a). The Agency considers that the problems and risks posed by eutrophication, together with the nature and complexities of the process, are sufficient to warrant a national strategy on this issue. Making best use of the regulatory framework is an important feature of the initiative. Equally important is the need to promote a partnership approach to the management of eutrophication, both at national and local level, because the control or management of eutrophication problems is often beyond the remit of any one regulatory body or other interested party.

2. EUTROPHICATION: ITS CAUSES AND IMPACTS

2.1 What is eutrophication?

The definition adopted by the Environment Agency is:

"The enrichment of waters by inorganic plant nutrients which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants, affecting the quality of the water and disturbing the balance of organisms present within it. Such changes may be undesirable and interfere with water uses."

The nutrient status of any environmental water is determined by the supply of nutrients from its catchment, which in turn is influenced by the geology. Thus waters will vary in their natural nutrient status. Enrichment and its impacts can occur if there are changes to the nature of the catchment. This becomes a concern when human

activities accelerate the enrichment process, and it is this cultural eutrophication which warrants attention.

2.2 Causes of eutrophication

The growth of plants in aquatic systems is influenced by a number of factors including the supply of nutrients, light, temperature, flow regime, turbidity, zooplankton grazing and toxic substances. These factors are affected in turn by the properties of the catchment and the water body and the impact of human activities. While it is important to understand the role of all these factors, it is widely accepted that the principal factor ultimately controlling primary production in environmental waters is the supply of nutrients. A conceptual diagram of the eutrophication process is given in Figure 1.

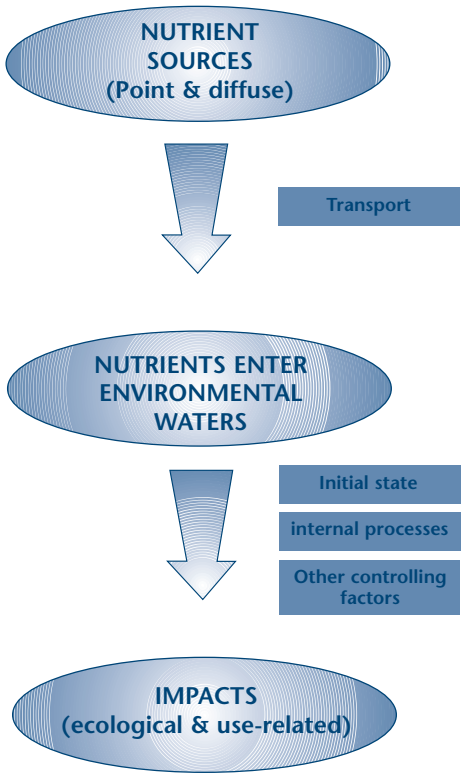

Figure 1. Conceptual diagram of the eutrophication process

In temperate freshwater systems, phosphorus is generally the key limiting nutrient (ie that which does or could control productivity). However, silicon may limit blooms of diatoms in spring and, in areas where phosphate levels are naturally high because of the underlying geology, waterbodies may be nitrate-limited, eg the meres of Shropshire and Cheshire (Moss et al., 1993). Estuarine ecosystems tend to show phosphorus-limitation at their freshwater extreme, grading through to nitrogen-limitation at their seaward end. However, the common occurrence of suspended sediments in estuaries often means that light limits algal growth. Where nutrients are the limiting factor in coastal waters, nitrogen is generally believed to be the key nutrient.

2.3 Sources of nutrients

Nutrient sources can be broadly segregated into two categories: readily identifiable point sources (such as sewage effluents), and diffuse sources (such as the run-off from agricultural land), with the relative contribution of each varying between catchments. These contributions will change with time, both in the short-term, in response to land management and climatic variation, and in the longer-term in response to technological advances, national and international regulations and voluntary codes of practice.

Figure 2 shows the contribution (in percentage terms) of the main sources of phosphorus entering surface waters in the United Kingdom (UK) (Morse et al., 1993). These figures are approximate national estimates but give an indication as to where control initiatives might best be targeted. The actual contributions in any given catchment will depend on the nature of the catchment and the human activities within it.

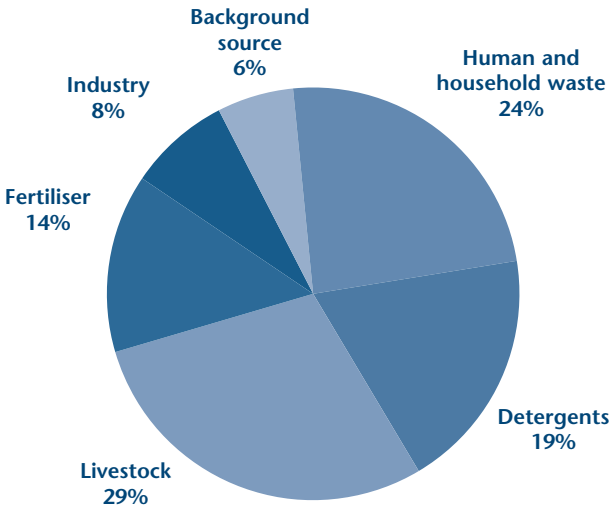

Figure 2. Major phosphorus inputs to surface waters in the UK (after Morse *et al.*, 1993)

For nitrogen, inputs to fresh waters in Europe come principally from diffuse sources, particularly agriculture, although point sources (usually urban waste water) also contribute significantly in many regions (European Environment Agency, 1998). In England and Wales 70% of the total input of nitrogen to inland surface waters is estimated to come from diffuse sources (agriculture, precipitation and urban run-off, in order of decreasing

importance). The remaining 30% comes from sewage effluent and industrial discharges (The Royal Society, 1983).

The magnitude of the sources is a further consideration. The UK ranks in the middle order of European Union (EU)/European Free Trade Association (EFTA) nations in terms of its land area but is the third-most populous, ranks second in terms of the proportion of land used for agriculture and, before the bovine spongiform encephalopathy (BSE) crisis, was third with respect to livestock numbers (Morse et al.,1993). Thus the UK is well endowed with the main sources (urban waste water and agriculture) of the nutrients associated with eutrophication. In terms of phosphorus loadings entering surface waters, the UK ranks third-highest out of 16 EU/EFTA nations (Morse et al., 1993).

2.4 Impacts of eutrophication: in general

Eutrophication can have both temporary and more irreversible effects on aquatic ecosystems. Significant fluctuations in dissolved oxygen concentrations between day and night can occur in waters where there is enhanced plant growth. This can cause problems in the early morning when low oxygen levels, the result of plant respiration, may lead to the death of invertebrates and fish. This process can be compounded when algal blooms, through their decay, further reduce the oxygen content of water. The formation of benthic (bottom-dwelling) mats of macro-algae can also lead to the deoxygenation of sediments.

Certain algal species, particularly freshwater blue-green algae, and marine dinoflagellates can produce toxins which may seriously affect the health of mammals (including humans), fish and shellfish. This occurs either through the food chain, or through contact with, or ingestion of, the algae. Other algal species cause fish deaths by physically clogging or damaging gills, causing asphyxiation.

Eutrophication ultimately detracts from biodiversity, through the proliferation and dominance of nutrient-tolerant plants and algal species. These tend to displace more sensitive species of higher conservation value, changing the structure of ecological communities. Eutrophication can also adversely affect a wide variety of water uses such as water supply (eg algae clogging filters in treatment works), livestock watering, irrigation, fisheries, navigation, water sports, angling and conservation. It can give rise to undesirable aesthetic impacts in the form of increased turbidity, discolouration, unpleasant odours, slimes and foam formation.

2.5 Impacts of eutrophication: the extent of the problem in England and Wales

Historically, successive UK administrations regarded eutrophication as an exacerbation of a natural phenomenon which gave rise to local problems in a small number of areas, notably the Norfolk Broads and Lough Neagh (Carvalho and Moss, 1995).

Recent evidence, particularly as regards the freshwater environment, indicates that aquatic eutrophication is more than a limited localised problem. The Agency's report on the state of the freshwater environment in England and Wales (Environment Agency, 1998a) identifies nutrient enrichment as one of ten priority issues to be addressed if a more sustainable balance between the needs of society and the health of freshwater ecosystems is to be achieved.

Details of the main impacts detected are summarised below, for each of the following three categories of waters:

- standing fresh waters (lakes and reservoirs)
- running fresh waters (streams, rivers and canals)
- estuaries and coastal waters

2.5.1 Standing fresh waters

Blue-green algal blooms in lakes and reservoirs have attracted considerable attention, particularly since the warm, calm summer of 1989 when toxic algal scums occurred in many standing fresh waters in England and Wales. 915 affected waters were inspected that year, of which 65% were found to have blue-green algae (cyanobacteria) as the dominant species (NRA, 1990). Toxicity tests carried out on a sample of these waters showed that 60-70% of blue-green algal blooms were producing toxins.

The problems caused in 1989 included: the deaths of sheep and dogs at Rutland Water in Leicestershire; the hospitalisation of two soldiers after canoe exercises at Rudyard Lake in Staffordshire; further reports of health effects, mostly gastro-enteritis and skin rashes (although many of these were unsubstantiated); and the cancellation of a number of recreational events and activities.

In response to the events of 1989, a Toxic Algae Task Group was formed, to provide advice to the NRA (and subsequently the Agency) and to increase public awareness of the risks and problems associated with blue-green algae.

From 1989 to 1997, some 3,000 different freshwater bodies (mainly standing, but also running waters) have been affected by algal blooms. Actions taken in response have ranged from notifying the users of potential risks, to closing waters for recreation. Of these waterbodies, approximately two-thirds had blue-green algae as the dominant species (Figure 3). In the majority of cases, the warning threshold - which indicates that there is a significant risk of a blue-green bloom or scum formation - was exceeded. The Agency monitors affected waters mainly on a reactive basis, tending not to revisit problem sites but instead advising caution, based on the probability of toxicity. The affected sites occurred throughout England and Wales but were most prevalent in the Agency's Midlands and Anglian Regions.

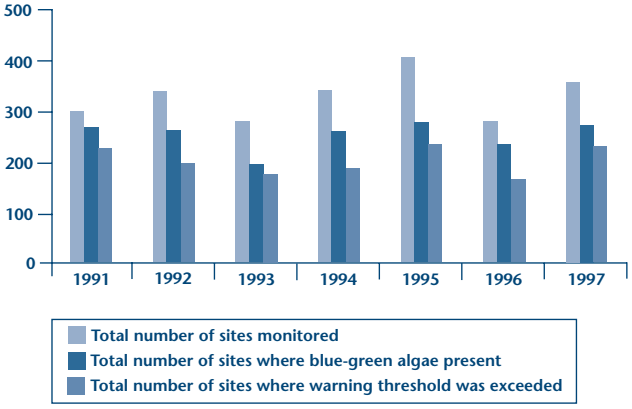

Figure 3. **Blue-green algal monitoring by the Environment Agency between 1991 and 1997**

Such problems were reflected in the Sixteenth Report of the Royal Commission on Environmental Pollution (RCEP, 1992), which referred to the widespread occurrence of eutrophic and hypertrophic lakes and reservoirs.

Work commissioned by the Agency in considering methods for classifying lakes, showed that the majority, from a sample of 76 lakes across England and Wales, were affected by eutrophication, assessed in terms of change in phosphorus and chlorophyll concentrations from an estimated 1930s baseline (Environment Agency, 1998b).

Eutrophication is also implicated in the depreciating conservation value of some of the country's more pristine lakes, as illustrated by the decline of arctic charr and vendace in some of the waters of the Lake District National Park. English Nature believes that eutrophication is adversely affecting many stillwater Sites of Special Scientific Interest (SSSIs). It commissioned a survey in 1994 which suggested that 84% out of a sample of 102 sites showed symptoms of eutrophication (albeit based on a primarily subjective assessment), and that in 68% of cases this "had overtly affected the nature conservation interest" (Carvalho and Moss, 1995).

2.5.2 Running fresh waters

As in standing waters, the symptoms of eutrophication in streams and rivers are diverse and assessing the extent of the problem is complicated by their dynamic nature. However, a number of waters have been identified as affected.

In 1994, the UK Government designated 33 Sensitive Areas (Eutrophic) in England and Wales under the EC UWWT Directive, relating both to standing and running fresh waters (mostly in central and south-eastern England). In 1998 it designated a further 47 waters (mostly rivers) on the basis of advice from the Agency, and a total of 2,540 km of 62 rivers/canals has now been designated. Figure 4 shows the location of designated waters (rivers/canals and also lakes/reservoirs and estuaries) in England and Wales. Under this initiative, waters receiving discharges from large STWs were assessed for the effects of eutrophication using chemical, biological and use-related criteria. Excessive weed growth and changes to macrophyte communities were the main ecological impacts detected, although benthic and floating mats of blue-green algae have caused problems in some slow-flowing rivers.

Figure 4. **Sensitive Areas (Eutrophic) designated under the UWWT Directive**

As regards sites of particular value for nature conservation, English Nature believes that eutrophication is adversely affecting a number of river SSSIs (English Nature, 1997). It is working with the Agency to identify sites for control action and/or more detailed investigation.

2.5.3 Estuaries and coastal waters

In comparison to the freshwater environment, the impacts of nutrient enrichment in estuaries and coastal waters are less well understood, making it difficult to make an authoritative assessment of the extent of problems in these waters. However, in contrast to parts of continental Europe, demonstrable impacts of eutrophication in the estuarine and coastal waters of England and Wales have been considerably less dramatic and more isolated. This is largely because the relatively small riverine inputs of nutrients, high turbidity and strong tidal mixing around the UK coast, reduce the likelihood of impacts occurring. However, there is some evidence of localised eutrophication in a small number of estuaries, as outlined below, and there is a need to keep the situation under review and to improve our understanding of the impacts of nutrients in saline waters.

Certain estuaries have been identified for investigation as "possible problem areas" with regard to eutrophication for Oslo and Paris (OSPAR) Convention purposes (OSPAR, 1993). These are Langstone Harbour (Hampshire), parts of the Wash estuary (East Anglia), and the Three Rivers estuary which forms Carmarthen Bay (Wales). In addition, in 1998 five estuaries were designated as Sensitive Areas (Eutrophic) under the EC UWWT Directive. The impacts which formed the basis of these designations were either excessive growth of green macro-algae (particularly *Enteromorpha* and *Ulva* spp.) in shallow sheltered estuaries, or micro-algal blooms in the deeper estuaries.

Current knowledge of the processes controlling the flow of nutrients to coastal waters should be improved through the findings of the Joint Nutrient Study (JoNuS) research project, coordinated by the Marine Pollution Monitoring Management Group. This project was set up in 1990 to establish nutrient budgets in the main estuaries opening into the southern North Sea (Humber, Wash and Thames), and to examine the fate and behaviour of nutrients as they are carried through estuaries. The JoNuS work has highlighted the difficulties in interpreting data on nutrient concentrations and ecological effects in coastal waters, given the poor understanding of the processes involved, and the difficulties of separating natural events from human-induced disturbances.

The Agency has responsibility for territorial waters to three nautical miles offshore and has been monitoring marine micro-algae since 1991 through its existing EC Bathing Waters Monitoring Programme (EC Directive 76/160/EEC). This monitoring has shown that there are some species which cause isolated algal bloom events (eg *Gyrodinium aureolum*, *Alexandrium tamarense*) and others whose occurrence is more regular and widespread (eg *Phaeocystis* spp.). From 1991 to 1995 the number of coastal monitoring sites with reported blooms has increased from 62 to 175, a small percentage (<10%) of which were potentially toxic.

The Agency would welcome views on the perceived importance of eutrophication as an environmental problem in different types of environmental waters (standing fresh waters, running fresh waters, estuaries and coastal waters).

2.6 Trends in nutrients and eutrophication

In considering nutrient enrichment and its impacts, it is appropriate to review whether the situation is improving or worsening. In doing so it is pertinent to consider trends in the sources of nutrients, the concentrations of nutrients in environmental waters, and the ecological and use-related impacts of eutrophication.

For phosphorus, there is evidence of a reduction of loadings to surface waters from STWs during the 1990s, attributable mainly to reduced use of phosphate in detergents (Environment Agency, 1998a). Furthermore, from 1999, some 51 STWs serving a population of around 4.5 million people will require phosphorus reduction treatment under the EC UWWT Directive, with a further 90 or so STWs by 2005, which should reinforce this trend.

The trend of falling phosphorus inputs from STWs has been matched by a fall in river phosphate concentrations between 1990 and 1995 (Environment Agency, 1998a), although levels remain high, in common with other western European countries. Geographically, the rivers in Wales and the west of England tend to have lower phosphate concentrations than those in the midlands, south and east.

With regard to agriculturally derived phosphorus, UK usage of phosphorus fertilisers has fallen slightly in the 1990s, while livestock numbers (excluding poultry) in England and Wales increased slightly from 1970 to the

early 1990s, albeit with a fall in the number of cattle (Environment Agency, 1996). Despite the falling trends in fertiliser use and cattle numbers, the contribution of agricultural phosphorus losses to eutrophication has become an increasing concern in recent years, since what are small losses in agronomic terms can have potentially significant impacts on aquatic ecosystems. Most UK farms, particularly those with livestock enterprises, operate on the basis of an annual phosphorus surplus, in common with agricultural practice in other European countries (Edwards and Withers, 1998). This generates a steady accumulation of excess phosphorus in soils and there is growing evidence that phosphorus is being transported to water from diffuse agricultural sources at rates which are increasing under modern farming methods (Withers and Jarvis, 1998). Even where phosphorus surpluses were reduced or eliminated, these soils could continue to contribute to elevated phosphorus concentrations in receiving waters for many years.

Concentrations of nitrate in the rivers and lakes of England and Wales (particularly southern and eastern England) are high, in common with other western European countries (European Environment Agency, 1994, 1998). Before the mid-1970s, nitrate concentrations had risen significantly since the 1930s in a number of catchments, reflecting changing agricultural practices. However, over the last twenty years, monitoring data for England and Wales confirm that nationally, there have been no significant changes in river nitrate levels, although there may have been marked changes in specific catchments (DoE, 1996). As regards sources, the UK use of nitrogenous fertilisers increased by around fifty percent from 1970 to the early 1990s (Environment Agency, 1996). Trends in inputs of nitrogen from STWs are not known. Monitoring data collected for OSPAR purposes show that while the loads of total phosphorus delivered to estuaries and coastal waters appear to have decreased in the early-1990s, the total nitrogen load has not (NRA, 1995). Total nitrogen inputs from individual estuaries have remained fairly constant in all but the Wash, where there appears to be a trend of increasing nitrogen load (Environment Agency, 1998a).

Few estuaries or areas of coastal water around England and Wales have comprehensive data-sets that show longer-term trends in nitrate concentrations. Exceptions include the Tweed and the Humber, where extensive data-sets collected between 1993 and 1996 under the Land Ocean Interaction Study (LOIS) have revealed important seasonal and annual trends in nitrate concentrations. The LOIS data also showed large spatial variation as to whether estuarine waters were N- or P-limited for algal or other plant growth (Jarvie et al., 1998).

Regarding the ecological and use-related impacts of eutrophication, no discernible national trends are evident. This is due partly to difficulties in determining the influence of factors such as the weather, and also to a lack of biological data and long-term records of use-related problems. There are some notable exceptions where extensive, historic data-sets have been collected in relation to well-studied waters such as the Norfolk Broads and the Lake District.

In a European context, the eutrophication problems in England and Wales nationally are arguably moderate in extent. A comprehensive pan-European assessment has yet to be undertaken. However, a preliminary review by Chiaundani and Premazzi (1988) indicated that the extent of the problem was greatest in Belgium, Denmark, Germany, Italy and the Netherlands, and moderate in Greece, Ireland, Luxembourg and Spain. In France the position varied across the country. It is anticipated that the European Environment Agency will address the need for more reliable information across Europe.

3. THE AGENCY: ITS APPROACH TO ENVIRONMENTAL MANAGEMENT

Consistent with its powers and duties relating to environmental management and its objective to help achieve sustainable development, the Agency has drawn up an Environmental Strategy for the Millennium and Beyond (Environment Agency, 1997). The strategy is based on the need to address the management of the environment in an integrated way, to form an overview of the state of the environment at any one time, to identify the pressures which affect that state, to determine the appropriate management responses, and to work in partnership with and through others to achieve agreed objectives. The application of this approach led to the identification of nine key environmental concerns which need to be addressed, together with a range of commitments in respect of each, as set out in the strategy. Some of these are directly relevant to eutrophication, as follows.

KEY ISSUE: *Enhancing biodiversity*
Among the intended actions in relation to this issue are commitments to:

> "control eutrophication, where feasible, in order to enhance biodiversity".
>
> "ensure that there is no deterioration in the quality of the aquatic environment in particular,

and deliver significant improvements in river and still water quality by tackling diffuse pollution of them".

KEY ISSUE: *Delivering integrated river-basin management*
Among the intended actions in relation to this issue are commitments to:

"ensure that all waters are of sustainable quality for their different uses".
"deliver a continual improvement in overall water quality".

KEY ISSUE: *Regulating major industries*
Among the intended actions in relation to this issue are commitments to:

"ensure improvements are made to the quality of discharges to estuarine and coastal waters".
"implement the requirements of the EC Urban Waste Water Treatment Directive".

The approach embodied in the environmental strategy will assist the delivery of the Agency's proposed strategy on eutrophication, by helping to put eutrophication in context with other environmental problems. It will also provide tools and mechanisms for assessing the state of, and the pressures upon, environmental waters and for implementing local improvements.

4. THE NEED FOR A STRATEGY ON EUTROPHICATION

4.1 The Agency's functions and eutrophication

Eutrophication can hinder the achievement of sustainable development and delivery of the following statutory responsibilities of the Agency for regulating and managing the water environment:

- *to preserve or improve the quality of rivers, estuaries and coastal waters;*

  Deteriorating water quality as a result of increased nutrient concentrations is the primary cause of eutrophication. Secondary impacts include deoxygenation and pH changes which occur during the daily cycling associated with excessive plant production and during algal decay. These impacts can adversely affect water quality and the biota. Algal blooms and excessive plant growth also detract from a wide range of water uses.

- *to promote the conservation and enhancement of inland and coastal waters, and their use for recreation;*

  Eutrophication is often implicated as a contributory factor in the depreciating conservation value of the country's more pristine waters, as it ultimately reduces biodiversity. In addition, the risks associated with toxic algal blooms can lead to the closure of waters for recreational purposes or restrictions on their use.

- *to exercise general supervision over all matters relating to flood defence, and maintain or improve non-marine navigation;*

  The build-up of aquatic vegetation and associated silt deposition affect the carrying capacity of channels and enhance the risk of flooding. Primarily for this reason, but also because of the hindrance caused to angling, recreation, navigation and irrigation, costly weed-control operations are undertaken every year.

- *to take any necessary action to conserve, augment and secure the proper use of water resources;*

  When they occur, blooms of blue-green algae limit the use of water resources for livestock watering, irrigation and other abstractions. They also lead to increased costs of treatment for potable supplies and, in extreme situations, can lead to the temporary loss of a potable supply resource.

- *to maintain, improve and develop salmon, trout, freshwater and eel fisheries;*

  Spring blooms of benthic algal mats and the resulting plant debris can hinder the supply of oxygenated water to eggs and redds, and impede the emergence of fry from salmonid spawning gravels. Eutrophication also influences the species composition of fish communities and can cause changes in the age structure of fish populations, particularly in shallow lakes, where younger fish may become predominant (Phillips et al., 1996).

The analysis in Section 2.5 indicates, particularly for the freshwater environment, that the impacts and/or risks associated with aquatic eutrophication in England and

Wales are significant. The proposed strategy is intended to provide a means of reducing those risks and impacts, and their effects on the Agency's compliance with its statutory responsibilities.

4.2 The regulatory framework for eutrophication control

In addition to its statutory duties, the Agency has powers relating to the aquatic environment and its management, some of which are either directly or indirectly relevant to the assessment and control of eutrophication. There are also a number of international commitments which can drive eutrophication control. The relevant legislation and commitments are briefly discussed below.

4.2.1 General powers to control pollution

The Water Resources Act 1991, as supplemented by the Environment Act 1995, is the principal piece of domestic legislation governing the operation of the Agency with respect to the aquatic environment. Those sections most directly relevant to eutrophication control are the provisions for:

- the establishment of schemes to classify the quality of controlled waters, and for a system of Statutory Water Quality Objectives (Sections 82 and 83);
- the control of point sources of pollution through consents to discharge (Section 88);
- the introduction of Regulations to prevent and control pollution (Section 92);
- the establishment of Water Protection Zones (Section 93) and Nitrate Sensitive Areas (Sections 94 and 95).

Discharges and emissions from certain industrial processes are also subject to control under the Environmental Protection Act 1990. Both the Water Resources Act 1991 and the Environment Act 1995 impose on the Agency general duties to further and promote conservation, especially for sites designated as SSSIs under the Wildlife and Countryside Act 1981.

The Agency's powers to control pollution from point source discharges are considerable and relatively straightforward in their application. In contrast, the regulatory mechanisms for controlling diffuse sources of pollution are more cumbersome, requiring the drafting of government regulations to prevent pollution from particular activities, or the definition, by ministerial order, of Water Protection Zones (WPZs) within which specific restrictions or prohibitions on particular activities are applied. Only one set of regulations (in relation to silage, slurry and agricultural fuel oil storage) has been produced and one WPZ has been piloted (for purposes other than eutrophication control).

Nitrate Sensitive Areas (NSAs) have, as yet, been defined only in relation to water supply sources with elevated nitrate concentrations. They could potentially be defined for eutrophication control purposes where nitrate was shown to be the principal cause, but this would seldom be the case in freshwater systems. In addition enforcement and monitoring of measures to control diffuse pollution is considerably more difficult than for point sources.

The provisions relating to the adoption of Statutory Water Quality Objectives (SWQOs) have been applied only on a pilot scale and not in relation to the control of nutrient pollution. Proposals for interim non-statutory phosphorus standards for rivers and lakes are discussed in Section 5.5.1.

4.2.2 Initiatives directly aimed at eutrophication control

The **Urban Waste Water Treatment Directive (91/271/EEC)** aims to "protect the environment from the adverse effects of urban waste water discharges and waste water discharges from certain industrial sectors". It sets minimum standards for the provision of sewage collection and treatment facilities and for effluent discharges, depending on the population equivalent (pe) served and the nature of the receiving water.

Secondary treatment is the norm for all discharges serving greater than 2,000 pe to inland waters and estuaries, and greater than 10,000 pe to coastal waters. However, laxer or more stringent requirements can be applicable under certain circumstances. Discharges of greater than 10,000 pe to waters identified by Member States as sensitive to eutrophication, termed 'Sensitive Areas (Eutrophic)', must comply with specified standards for phosphorus and/or nitrogen (depending on the situation), in addition to the secondary treatment requirements. Sensitive Areas may be fresh or saline waters which are eutrophic, or which may become so in the near future if protective action is not taken. The nutrient removal requirements are to be

enforced by the Agency through its discharge consenting procedures, from 31.12.98 onwards.

Criteria for identifying Sensitive Areas were provided, in a government consultation paper, for different types of environmental waters. The designation of the areas is the responsibility of ministers, taking into account the advice of the Agency. Sensitive Areas must be reviewed at least every four years, with a seven year lead-in time for bringing newly identified qualifying discharges to the required standard. To date, 80 such areas have been designated in England and Wales, of which 62 are rivers or canals, 13 are lakes/reservoirs and 5 are estuaries. A shortcoming of the initiative, as a general tool for eutrophication control, is the pe threshold of 10,000. Discharges from treatment works serving smaller populations are a significant source of phosphorus in some catchments.

The objective of the **Nitrate Directive (91/676/EEC)** is to "reduce water pollution by nitrates from agricultural sources, and to prevent further such pollution". The Agency's responsibility is to advise the government on the identification of waters as "polluted" if they show signs of eutrophication (induced by excess nitrates), or if they are used for drinking water abstraction and have elevated nitrate concentrations. Where a water body is identified as polluted, its catchment must be designated as a Nitrate Vulnerable Zone (NVZ), within which farmers must comply with mandatory restrictions aimed at reducing nitrate leaching. To date, 68 NVZs in England and Wales have been designated by the government, covering some 600,000 hectares in total, but none of these zones relate to waters affected by eutrophication. The Agency will be responsible for enforcing and assessing compliance with the measures when they come into force in December 1998. The Directive has certain limitations as a general eutrophication control tool. It applies only to waters which are eutrophic due to nitrogen compounds, so its relevance is primarily restricted to saline water situations.

The European Commission's **proposed Water Framework Directive (COM(97)49 final)**, if and when adopted, may be an important vehicle for the control of eutrophication. The proposal is intended to provide for a coordinated approach to sustainable water management, through river-basin management plans, assessing the state of waters and the sources of pollution, then formulating and implementing improvement plans. The objective is to achieve good water status, with an emphasis on achieving good ecological quality, which will include avoidance of the effects of eutrophication. The improvement measures will comprise those required by existing Directives (such as those relating to urban waste water and agricultural nitrates), supplemented by whatever additional measures are needed to control pollution sources, point or diffuse, to achieve the stated objective. The Agency is following closely the progress of this proposal, and considering how best the Directive could be implemented.

In addition to the EC Directives, a range of international commitments include elements that are directly relevant to eutrophication control. The problem of eutrophication in the North Sea was recognised at the Second North Sea Conference in 1987. The countries bordering the North Sea agreed to reduce anthropogenic inputs of hazardous substances from land-based sources to the North Sea by 50% between 1985 and 1995. For nutrients, the commitment related only to eutrophication problem areas, where inputs were likely (directly or indirectly) to cause pollution. While a number of potential problem areas in the UK are currently being considered, none have been formally established. The commitments on marine eutrophication were subsequently embodied in recommendations of the **OSPAR Convention**. In 1998, the contracting parties to OSPAR, including the UK Government, adopted a strategy to combat eutrophication (OSPAR, 1998). The Agency's involvement in these initiatives is primarily in providing data and advice to government departments.

4.2.3 Initiatives providing indirect control of eutrophication

The **Habitats Directive (92/43/EEC)** enables the designation of Special Areas of Conservation (SACs), in which rare and endangered habitats and species must be protected. The competent authorities for this legislation are, among others, the conservation agencies and the Agency. If eutrophication threatens the conservation status of freshwater or marine SACs, there may be a need to impose nutrient control requirements on discharges. The Agency must review its consents to ensure that the designated sites are adequately protected. Sites designated as Special Protection Areas (SPAs) under the EC **Wild Birds Directive (79/409/EEC)** will receive the same protection.

On a more global scale, the Earth Summit Conference in Rio do Janeiro in 1992 resulted in the UK entering into commitments to safeguard the well-being of the planet. The outputs of the Conference most relevant to eutrophication were the signing of the Convention on Biological Diversity, requiring the development of national strategies, plans or programmes for the conservation and

sustainability of biological diversity, and the agreement of Agenda 21, a comprehensive programme of world-wide action to achieve sustainable development. A UK Biodiversity Group has been set up to take forward the Government's commitments to prevent the loss of species and habitats under the **UK Biodiversity Action Plan**. Action Plans for priority habitats and species provide a non-statutory framework within which the Agency and others can make a contribution. This will particularly apply in relation to plans such as those for chalk rivers and mesotrophic lakes, and that proposed for eutrophic lakes, where control of eutrophication will be important in maintaining or restoring biodiversity.

The **Freshwater Fish Directive (78/659/EEC)** and **the Surface Water Abstraction Directive (75/440/EEC)** define standards for different nutrient parameters in designated waters. These tend to be Guide, rather than Imperative, standards. While there is an Imperative standard for nitrate in the Surface Water Abstraction Directive, it is set at a level intended for the protection of drinking water, rather than the control of eutrophication. Eutrophication may also lead to failures in some of the Freshwater Fish Directive parameters for which Imperative standards are set, particularly dissolved oxygen and pH. The **Directive on Integrated Pollution Prevention and Control (96/61/EC)** will supplement the processes controlled under the Environmental Protection Act 1990, and includes the control of pollution from intensive livestock units.

There are increasing pressures on the agricultural industry to develop more environmentally sustainable farming methods. The importance of this is recognised by the EU in Council Regulation (EEC/2078/92) - 'to encourage agricultural methods compatible with the requirements of the protection of the environment and maintenance of the countryside'. In England and Wales this is being implemented through agri-environment schemes where grants are offered by the Ministry of Agriculture, Fisheries and Food (MAFF) for farming in a more environmentally sympathetic manner. Uptake is on a voluntary basis. The major schemes are:

- **Countryside Stewardship**, a discretionary scheme aimed at conserving, managing and recreating valued landscapes; and
- **Environmentally Sensitive Areas**, intended to introduce or maintain farming practices in particularly sensitive or valued areas of countryside.

In addition, one option of the **Habitat Scheme**, allows for the creation of buffer strips of land adjacent to water bodies to reduce diffuse pollution and siltation and enhance wildlife habitat. The Agency understands that the future of this scheme is currently under review and that it is likely that waterside margins would then only be covered within Countryside Stewardship.

Compliance with the **Codes of Good Agricultural Practice**, published by MAFF and the Welsh Office Agriculture Department (WOAD), is an important requirement of the agri-environment schemes. The codes (for the protection of water, soil and air) (MAFF/WOAD, 1998a, 1998b, 1998c) are also an important vehicle for promoting best environmental practice nationally (see also Section 5.8), providing practical guidance to farmers and growers on avoiding water and air pollution or long term damage to soils. The Water Code is a statutory code under Section 97 of the Water Resources Act 1991. Non-compliance is not an offence, but can be taken into account in any legal action and following the code is not a defence against a charge of causing pollution.

In the longer term the reform of the **EU Common Agricultural Policy** (CAP) has perhaps the greatest potential to bring about the general adoption of more environmentally sustainable agricultural practices. Environmental reform of the CAP is being addressed through an EU initiative entitled **Agenda 2000**. The Agency will contribute to the UK input to this debate, in liaison with MAFF and others.

4.2.4 Conclusion

A considerable body of legislation is available to the Agency for the control of water pollution in general. However, for diffuse pollution, and that from nutrients in particular, the regulatory framework is somewhat cumbersome, untested in practice as far as phosphorus from agriculture is concerned, and would be difficult to enforce. The promotion and adoption of best environmental practices is crucial to ensure the reduction and prevention of pollution from diffuse sources such as agriculture. The mechanisms for achieving these ends extend beyond the remit of any one regulatory body.

The initiatives aimed directly at the control of eutrophication (such as the EC UWWT and Nitrate Directives) generally provide only partial solutions to any problems, since in many situations they control only part of the total anthropogenic nutrient source. Furthermore, these initiatives, and those which potentially provide for

indirect control of eutrophication, contain no detailed methodologies for the assessment of eutrophication problems and nutrient contributions, nor in some cases for the determination of appropriate control measures.

An approach is required which allows for best use to be made of the somewhat patchy and disjointed regulatory framework and, where traditional regulatory methods alone are considered inadequate or inappropriate, for collaborative initiatives to be used as a supplementary or alternative approach (see 5.2).

4.3 Catchment-based management within a national framework

From 4.2.4 above, it is clear that a more holistic, catchment-based approach is required, assessing the nature of any eutrophication-related problems, quantifying the relative contributions of the key nutrient sources and assessing what combination of management actions would most effectively address the problems and what mechanisms would best achieve their implementation. This can best be pursued within a national framework for the assessment, and where feasible, control of eutrophication, so that local actions are addressed in the light of best available tools/techniques/practices and prioritised within the context of the national picture. There is also a need to consider what nutrient source/loss reductions might be achieved through higher (national and international) level initiatives.

The Agency invites comments on its proposal to manage eutrophication through the development of catchment-based action plans within the context of a national framework (see also Section 5.6).

5. THE PROPOSED MANAGEMENT STRATEGY

5.1 Expectations and public awareness

In addressing the risks and impacts associated with eutrophication, it is important that the difficulties and uncertainties of managing eutrophication are recognised. Eutrophication is a process and it can be difficult to decide at which point action should be initiated. Impacts can be unpredictable due to the influence of changing weather conditions from year to year. In some instances, long-term trends are difficult to discern because of a lack of historic data.

For some nutrient sources and certain types of waters, the transport mechanisms which deliver nutrients to environmental waters, and the internal processes once they enter a water body, are not fully understood. Factors other than nutrients can also have a major influence in some situations. All of this makes it difficult to determine cause and effect, to set meaningful environmental objectives and to decide with confidence upon control options. Where controls are implemented, there can be a considerable time-lag before ecological improvements occur eg due to internal recycling of nutrients from sediments within lakes and slow-flowing rivers, or delayed groundwater contributions. Cheap, rapid and reliable solutions to problems are not always available.

Although many people are aware of toxic blue-green algal problems in lakes and reservoirs (through leaflets and press coverage), the other effects of eutrophication may only be recognised by those whose work and leisure are related to the aquatic environment - such as nature-enthusiasts, anglers, participants in water sports, people working in aquaculture and other water-based industries. Similarly, the public may be unaware of the role of nutrients in promoting algal blooms and the excessive growth of other aquatic plants, or that those nutrients originate from wastes produced by people and businesses, and from the products which they use.

Communication must therefore be an important element of the strategy. The Agency intends to do more to enhance public awareness of eutrophication as an environmental issue, while not raising false expectations, through the use of balanced education campaigns. Measures that could contribute to such campaigns might include:

- the continuing production of state of the environment reports, showing the extent of eutrophication problems while also enabling these to be seen in context with other environmental issues;
- the Local Environment Agency Planning (LEAP) process (see Section 5.6);
- the establishment of demonstration sites or catchments, associated with the development of pilot Action Plans, where eutrophication control, and its benefits, could be observed;

- the production of educational videos;
- further production and distribution of leaflets and posters, written in non-scientific language;
- the involvement of schools and universities through educational projects.

The Agency would welcome comments on these proposals for raising awareness of eutrophication as an environmental issue.

5.2 Promoting a partnership approach

5.2.1 Collaboration locally

While in some situations the control of a dominant point source of nutrients through regulatory measures may provide a straightforward remedy to a particular local eutrophication problem, in many cases diffuse nutrient sources will also be important. Influencing land-owners and others to reduce diffuse nutrient losses is more difficult, as these losses are not readily subject to regulatory control. In many cases, diffuse losses may be best addressed without enforcement measures, by promoting shared ownership of a local problem among a range of interested parties, through persuasion (where necessary with financial incentives) and the provision of advice and information. A collaborative approach is often also appropriate to deliver other management actions, beyond nutrient reduction measures, which may be required in order to prevent or alleviate eutrophication problems, for example, de-stratification or biomanipulation.

Therefore, in cases where different sources of nutrients contribute to a local eutrophication problem, and particularly where diffuse sources are significant, the Agency intends to promote a partnership approach to the management of the problem. Further details are given in Section 5.6 on Catchment-based Action Plans.

5.2.2 Collaboration nationally

In addition to local considerations, it is appropriate to address eutrophication at national level, to review what reductions in nutrient pollution have been and, importantly, what might be achieved through higher level initiatives, by collaboration with government departments, other regulators, relevant industrial sectors and other parties. The mechanisms available include regulation, voluntary agreements, education/advice and economic instruments, resulting either in general measures for application nationally (eg based on waste minimisation, best practice and sustainability), or more stringent measures for use locally, within vulnerable/sensitive catchments.

Liaison with government departments and other regulators will assist in promoting the development of integrated policies and a consistent national framework for eutrophication management. The process will build on the Agency's existing close links with the following organisations:

- Department of the Environment, Transport and the Regions (DETR);
- Ministry of Agriculture, Fisheries and Food (MAFF) and its executive agencies eg the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and the Farming and Rural Countryside Agency (FRCA);
- English Nature and the Countryside Council for Wales;
- Scottish Environmental Protection Agency (SEPA), Department of Agriculture for Northern Ireland, and Environment and Heritage Service, Department of the Environment for Northern Ireland;
- local authorities (eg Environmental Health Officers (EHOs)); and
- other organisations, eg the Broads Authority.

Development and/or implementation of the relevant Biodiversity Action Plans, the EC Urban Waste Water, Nitrate and Habitats Directives, the proposed Water Framework Directive and OSPAR commitments already provide a focus for collaboration. The Agency sees these measures as an important contribution to its proposed strategy on eutrophication and will promote improved coordination and synergy between the various initiatives.

With regard to nutrient contributions from agriculture, MAFF and DETR will be important partners, particularly in respect of advice to farmers (eg via the Codes of Good Agricultural Practice), use of agri-environment incentives and reform of the CAP via Agenda 2000 (see 4.2.3).

The Agency will explore with MAFF and others, appropriate mechanisms and schemes for addressing agricultural contributions to eutrophication. This will include the applicability and potential role of agri-environment schemes (see 4.2.3) for reducing agricultural nutrient losses in areas affected by eutrophication. The use of economic instruments, as a potential mechanism for pollution control, is an example of an issue on which the Agency believes that further debate is required at national level. The Agency's preliminary view is that economic instruments may have a potential role to play in promoting best practice, by using the receipts to fund education and training, providing the practical difficulties can be overcome. Such an approach would need to be seen as complementary, rather than an alternative, to other mechanisms for pollution control.

The Agency welcomes views on the need to manage the risks and impacts of eutrophication through a mix of regulatory and other (voluntary, collaborative, educational and economic) mechanisms. In particular, comments are invited on the merits of economic instruments and agri-environment incentive schemes as potential mechanisms for reducing agricultural nutrient losses.

Continued liaison with nutrient producers and users will also be important, to provide a forum to discuss best practice, the broader issues of shared ownership of the problem, and contributions to the solutions. The main organisations involved are anticipated to be:

- the water industry, through Water UK
- the Fertiliser Manufacturers' Association (FMA);
- the National Farmers' Union (NFU), the Farmers' Union of Wales (FUW), and other relevant farming bodies; and
- the Soap and Detergent Industry Association (SDIA).

In addition to trade organisations, the Agency proposes also to consult with individual companies, major retailers and water-user groups affected by eutrophication. The latter would include angling and boating associations and bodies representing other recreational users. Research and academic institutions will also have an important role to play in developing scientific knowledge and understanding. It may be helpful to promote discussions between regulators, nutrient-producers, nutrient-users and water-users, to help the different parties to understand each other's needs and to build consensus.

The views of others on the Agency's intention to promote a partnership approach to the management of eutrophication, both at local and national level, would be welcomed.

5.3 Measuring the extent and risks of eutrophication

While the Agency believes that the extent and risks of eutrophication in England and Wales are sufficient to warrant a strategy, it will continue to assess and interpret data from a variety of sources to determine the position more completely. In addition, it will review arrangements for measuring eutrophication in different types of environmental waters, to improve future assessments.

Where the monitoring data are suitably robust, maps and databases will continue to be produced to demonstrate the national picture and to assist in the identification of priority problem areas. Using a Geographic Information System (GIS) approach, the overlaying of maps of different eutrophication indicators might suggest correlations between chemical and biological parameters, as in the recent Agency report on fresh waters (Environment Agency, 1998a). This will help to focus further studies to improve our understanding of the relationships between nutrient concentrations and the biological expression of eutrophication.

Where gaps in the data significantly affect the Agency's ability to assess the causes and extent of eutrophication, monitoring programmes will be adjusted or extended. For example, the use of macrophyte and diatom communities as biological indicators of eutrophication is being reviewed, with a view to their wider implementation. The proposed EC Water Framework Directive will increase the need for biological monitoring. A better understanding of the role of sediments as nutrient sources and sinks may require a wider assessment of parameters such as the Equilibrium Phosphorus Concentration. Recognising that the symptoms of eutrophication are more diverse than phytoplankton blooms alone, more attention may need to be given to monitoring benthic algae in rivers and estuaries. Additional monitoring of effluent nutrient loads may also be required.

The Agency intends to ensure that it monitors consistently the most ecologically-relevant parameters, and to suitable limits of detection. Sampling, storage and analytical procedures may need to be amended, for example to ensure that detection limits for phosphorus fractions and total phosphorus are adequate for the protection of pristine waters, and to determine best practice in the measurement of chlorophyll. Monitoring will also be important in assessing the success of eutrophication control measures, once these are implemented.

In the following sub-sections, the Agency's overall approach to environmental monitoring is outlined in brief, followed by some further discussion of the potential to refine current programmes and methods for assessing the extent of eutrophication, in different types of environmental waters.

5.3.1 The Agency's approach to measuring the state of the environment

In 1997, the Agency published a consultative document entitled Viewpoints on the Environment, proposing a national framework for environmental monitoring and assessment. The approach, which was endorsed through the consultation process, involves the application of the following six complementary 'viewpoints' for measuring the state of the environment:

- land-use and environmental resources;
- key biological populations, communities and biodiversity;
- compliance with environmental standards and targets;
- the "health" of environmental resources;
- environmental changes at long-term reference sites;
- aesthetic quality of the environment.

Using the viewpoints methodology, together with a further framework for assessing the pressures on the environment, will enable the Agency to identify problems and determine priorities for action in a consistent manner. The Agency is reviewing its monitoring programmes in the light of the new frameworks, including the arrangements for assessing nutrient enrichment and eutrophication. Eutrophication is primarily associated with the viewpoint relating to the 'health' of environmental resources, since it is generally an indicator of poor 'health' in the aquatic environment. Measuring the status of key biological populations and communities should also provide useful information regarding the biological impact of eutrophication. The other viewpoints are also relevant to varying degrees.

5.3.2 Measuring eutrophication in standing fresh waters

For standing fresh waters, routine monitoring has been considerably less extensive than for rivers. However, the Agency is currently developing monitoring and classification schemes for lakes, based on chemical, biological and hydrological parameters. This has the potential to allow standing waters to be assessed for the impacts of eutrophication, both in terms of spatial state (comparing one lake to another in relation to arbitrary class boundaries) and in terms of degree of change through time (measured against a baseline state estimated through a technique known as 'hindcasting'). The latter method is considered particularly relevant in the assessment of eutrophication, since knowledge about the degree of change can be valuable in determining the need for preventative or remedial action.

The Agency will continue to collate information on the incidence of potentially toxic algal blooms in lakes and reservoirs in order to determine spatial and temporal trends. Most of this monitoring is reactive, following requests from owners or water-users, and the findings are then used to warn the owners and users of affected water bodies of the potential risks. A small number of waters are monitored on a regular basis as part of a long-term monitoring programme for blue-green algae and related parameters. Historical lake data-sets are also available from research organisations working in intensively studied areas such as the Lake District and the Norfolk Broads. Long-term monitoring of algae, macro-invertebrates, macrophytes, diatoms and nutrients at the 38 freshwater sites which constitute the Environmental Change Network (ECN) in the UK (coordinated by the Natural Environmental Research Council (NERC)) should also provide useful data.

The Agency has been exploring the use of aerial surveillance to obtain better information on the spatial extent of algal blooms. Such techniques would need to be targeted carefully to take into account the strong influence of climatic conditions on the occurrence of blooms.

Details of use-related impacts are also gathered, such as the extent of closure of waters for recreational use as a result of toxic algal blooms, but there is a need to improve the recording and collating of such information.

5.3.3 Measuring eutrophication in running fresh waters

The Agency has a well-established network of around 8,000 General Quality Assessment (GQA) routine monitoring sites, representing 40,000 km of rivers and canals. The GQA monitoring scheme is designed to provide an accurate assessment of the state of water quality (chemical and biological) across England and Wales and to identify changes over time. Since 1994 the Agency has been piloting a nutrients 'window' of the scheme, initially based on average phosphate concentrations. Nitrate data have also been collected in advance of the development of a nitrogen GQA. The nutrients GQA is already assisting in revealing both spatial and temporal trends.

Long-term monitoring of a wide range of parameters, including nutrients, has been undertaken since 1974 through the Harmonised Monitoring Scheme. The monitoring points are positioned at or close to the tidal limit of larger rivers and enable trends in nutrient concentrations (and loads), passing down rivers into estuaries, to be determined.

Relating extremely high or low dissolved oxygen measurements, collected during routine monitoring, to the growth of algae or other water plants can be one indication of the impacts of eutrophication.

Regarding the ecological effects of nutrient enrichment, the Agency has been developing methods for assessing the trophic status of rivers using macrophytes and diatoms as indicators. The differing tolerance of certain macrophyte and diatom species to nutrient enrichment can be used to assess the degree of ecological impact. The macrophyte scheme in particular has been applied successfully in assessing the extent of eutrophication in rivers that receive large sewage effluent discharges, for the purposes of the UWWT Directive. The wider application of these techniques is being considered, for example by not limiting the use of the methodology to river stretches affected by large sewage effluent discharges. The use of biological indicators of this type is considered particularly useful because they give a direct measure of the eutrophication response.

As for standing fresh waters, the Agency will continue its work recording (and responding to) the occurrence of potentially toxic blooms of planktonic and benthic blue-green algae in rivers, and the problems which these cause.

In relation to the UWWT Directive, the Agency has been collating chemical and biological data, as well as information on the use-related impacts of eutrophication in rivers, to advise the government on their potential for designation as Sensitive Areas (Eutrophic). The data are compared to indicative criteria for identifying waters affected by eutrophication, developed by the government and regulatory bodies (including the Agency) (DoE/MAFF/Welsh Office, 1993). These parameters include phosphate, dissolved oxygen, chlorophyll a, retention time and effects on flora and fauna. While the criteria were developed for the purposes of the UWWT Directive, their use and the collation of data/information on the chemical, biological and use-related impacts are considered useful in assessing impacts more generally. The government criteria include separate sets of indicative criteria for standing fresh waters, running fresh waters, and saline waters. Those for rivers are considered the most workable in practice.

5.3.4 Measuring eutrophication in estuaries and coastal waters

Scientific understanding of the processes that drive eutrophication in saline waters is incomplete and it can be difficult to determine the influence of anthropogenic activities in assessing impacts. However, considerable investment has been committed in recent decades to the study of nutrients and their impacts in estuaries and coastal waters, often involving close collaboration between government departments, regulatory bodies such as the Agency and other interested parties. In addition, a significant amount of monitoring is undertaken nationally, which is adding to our improving knowledge in this area. The principal initiatives are set out below.

Since 1991 the Marine Pollution Monitoring Management Group has been developing a National Monitoring Programme for the UK, involving regular monitoring of nutrients and chlorophyll (among a wide range of parameters) at selected estuarine and coastal water monitoring locations. The programme is designed to establish the spatial distribution of contaminants, the biological status of the waters and trends in key chemical parameters. The Agency is one of a number of UK organisations involved in this monitoring initiative.

In addition, the Agency has conducted baseline surveillance monitoring of the coastal waters of England and Wales over the last five years, for nutrients, chlorophyll and other water quality parameters. This comprises four surveys per year, involving the use of coastal survey vessels in conjunction with remote sensing from aircraft using a compact aerial spectographic imager (CASI), intended to identify seasonal and annual changes in water quality around the coastline. The Agency is also investigating the use of fixed buoys to obtain better information on temporal trends in nutrient concentrations. In the light of new technology, the Agency is reviewing methods for assessing the state of coastal waters.

With regard to algal blooms around the coastline, the Agency routinely monitors waters identified under the EC Bathing Water Directive (76/160/EEC). Where, in the course of this work, potentially toxic or nuisance algal blooms of marine algae are found, these are sampled and/or recorded and local EHO/MAFF officials are informed so that any health implications may be addressed. In an exchange of information, CEFAS advises the Agency on any significant algal blooms discovered via its monitoring of shellfish harvesting areas for the purposes of the Shellfish Hygiene Directive (91/492/EEC).

The Agency is also monitoring estuarine and coastal waters for the purposes of the UWWT Directive, to assess the degree to which sewage effluent discharges are contributing to the potential for eutrophication. The same monitoring can also be used to assess whether agricultural nitrates are giving rise to eutrophication problems, as required by the EC Nitrate Directive. In shallow estuaries, the extent of macro-algae is measured because this can be an indication of eutrophication.

Nutrient loading data for major rivers are collected for OSPAR purposes, by measuring river flow and nutrient concentrations at the tidal limit of rivers. In addition, the first step of the 1998 OSPAR strategy to combat eutrophication in the North Sea involves the application of a Common Procedure for identification of eutrophication status of marine waters. Areas of the North Sea will be assessed using this methodology, to determine whether they are problem areas, potential problem areas or non-problem areas with regard to eutrophication. The Agency is likely to be a source of data and advice in the government's application of this initiative.

Collaborative monitoring is also undertaken for specific projects aimed at improving understanding of nutrients and their impacts in saline waters, such as JoNuS (Section 2.5.3), the Land Ocean Interaction Study (LOIS), and the Southern Nutrient Study (SoNuS). LOIS is a large, six year programme of integrated work (1992-1998), involving numerous organisations and universities (coordinated by the Plymouth Marine Laboratory), seeking to quantify the exchange, transformation and storage of materials at the land-ocean boundary, and to determine how these parameters vary in time and space. SoNuS is aimed at establishing the nutrient status of the waters of the English Channel between the Isle of Wight and the Straights of Dover, and is carried out by the Southampton Oceanography Centre (SOC).

Concern about the potential for subtle impacts of nutrient enrichment in certain estuaries of high conservation status is likely to require further research and monitoring.

5.3.5 Use of risk assessment

While existing problems represent those situations where eutrophication risk has been realised, the wider assessment of risk will provide an early warning system for future problems. This is essential where the principal aim is to protect waters, rather than to try to rehabilitate them. In addition, the Agency must target its monitoring efforts to ensure maximum value from the resources available. It intends therefore to develop risk assessment systems to help target monitoring and protective measures against eutrophication in the most cost-effective manner. As a first step, these will build upon existing systems eg the export co-efficient modelling and 'hindcasting' methods developed for the Agency's proposed lake classification scheme, and the MINDER model (Models the Input of Nutrients and Determines the Eutrophication Risk) for lakes (Johnson et al., 1992) and rivers (Woodrow et al., 1994).

The Agency welcomes views on the proposal to review arrangements for assessing the extent of eutrophication in different types of environmental waters (Section 5.3)

5.4 Setting priorities for eutrophication management

There are two aspects to the determination of priorities for eutrophication management. Firstly, the relative importance of eutrophication in the context of other environmental issues, and secondly, the need to prioritise

those waters considered to be affected by, or at risk from, eutrophication.

The significance of eutrophication, compared to other environmental problems can be determined nationally through the Agency's integrated approach to assessing the state of the environment and the pressures upon it, as set out in the Environmental Strategy. The Agency produces periodic reports on the state of the environment, such as the recent document on fresh waters (Environment Agency, 1998a), which allow the relative importance of specific issues such as eutrophication to be determined. The same integrated approach is also applied at the local level, through the LEAP process (see Section 5.6), which entails local consultation to identify environmental priorities for action within individual river catchments.

Deciding priorities between sites considered to be affected by eutrophication can also be addressed at different levels, through national, regional or local assessment procedures. This will require the collation of information on impacts and risks, and the application of scoring systems or decision trees. The Agency has some experience of this approach in assessing waters affected by blue-green algal problems, and in considering candidate waters for designation under the UWWT Directive.

The Agency proposes the following five inter-related criteria for use in prioritising waters.

i. The presence of a statutory driver or international commitment

Waters requiring action to control eutrophication for the purposes of the following initiatives will form the initial core of priority sites nationally.

- EC UWWT Directive - designation as a Sensitive Area (Eutrophic) where waters are affected by eutrophication as a result of nutrient enrichment from large sewage effluent discharges (see 4.2.2).
- EC Nitrate Directive - designation of a Nitrate Vulnerable Zone in relation to waters affected by eutrophication due to pollution by nitrates from agricultural sources (see 4.2.2).
- EC Habitats Directive - designation as an SAC or SPA where the conservation interest of the site is threatened by nutrient enrichment resulting from consented activities (see 4.2.3).
- Designation as a SSSI - the Agency is liaising with the conservation agencies (English Nature and the Countryside Council for Wales) to identify river and lake SSSIs requiring action in cases where nutrient enrichment, particularly from sewage effluent discharges, is adversely affecting the conservation interest of the sites (see 4.2.1).
- UK Biodiversity Action Plan - sites identified as priority habitats where eutrophication control may be important, particularly chalk rivers, mesotrophic lakes, and eutrophic lakes (see 4.2.3) or sites hosting priority species where eutrophication is identified as a major threat.
- The OSPAR convention - marine waters identified as requiring action following the application of the Common Procedure (see 5.3.4) for identification of eutrophication status.

The proposed EC Water Framework Directive, when adopted, will be an important addition to this list (see 4.2.2).

It will be important to consider and, where appropriate, to build upon the assessments and control measures driven by these initiatives, in order to maximise the benefits of the associated investment. The above drivers potentially provide for protection of waters across the trophic range, from our most pristine oligotrophic (low nutrient status) sites, to more eutrophic (nutrient enriched) waters.

ii. The strength of evidence on cause and effect

The degree of scientific understanding of the link between cause and effect will be an important factor in prioritisation, particularly in the absence of a statutory driver. This consideration must encompass knowledge about the extent to which plant growth is limited by nutrients in a particular water body, the role of other environmental factors and the relative contributions of different nutrient sources. As current knowledge tends to be more advanced for standing fresh waters than for running fresh waters, and least advanced for estuarine and coastal waters, lakes and reservoirs are more likely to emerge as priorities under this criterion. Waters that are currently the subject of intensive monitoring and research are also likely to qualify as future priorities.

iii. The conservation value of the water body

These waters will be identified with the help of English Nature and the Countryside Council for Wales. They will

include more isolated pristine waters that are as yet unaffected by significant nutrient inputs, and also waters that support unique flora and fauna but are affected by the early stages of eutrophication. The protection of these sites is important because they can be vulnerable to significant, rapid and sometimes irreversible changes as a result of relatively small increases in nutrient concentrations. The most important sites are likely to be SSSIs and priority sites under the UK Biodiversity Action Plan and the EC Habitats Directive. In a few cases, the conservation status of the water body is maintained by high nutrient concentrations and it would be inappropriate to attempt to reduce nutrient inputs.

iv. The extent to which water uses are adversely affected

The Agency has been collating information on sites where uses are affected by blue-green algal blooms. In addition, for waters designated as Sensitive Areas (Eutrophic) under the UWWT Directive, details of use-related impacts due to other symptoms of eutrophication have also been gathered. Further information will also be generated through the Agency's LEAP consultation procedures.

v. The risk of deterioration

Catchments in which development (particularly population growth or agricultural intensification) could lead to an acceleration of eutrophication will be identified. This will be facilitated by the application of techniques to measure risk.

Having set priorities, the Agency's intention is that control action, beyond that required as a result of the statutory drivers should take into account the costs and benefits of proposed actions, so as to avoid the imposition of excessive or unnecessary costs on society.

On the basis of the above criteria, the initial priorities for action will be sites:

- where there are statutory drivers or international commitments for eutrophication control; or,
- where water uses, particularly water supply and recreation in lakes and reservoirs, suffer severe disruption from the effects of algal blooms; or,
- where there is special conservation interest, particularly where the waters are at risk of deterioration; or,
- where the benefits can be delivered, or deterioration prevented, with adequate confidence, at reasonable cost.

The Agency welcomes views on the proposed approach to the prioritisation of waters for management action, and on the initial priorities outlined above.

Notwithstanding this consideration of priorities, the Agency will continue to refine and implement its procedures for responding to potentially toxic algal bloom incidents, particularly those involving blue-green algae, which may pose a threat to public health or the environment.

5.5 Objectives and targets

An important step in considering control action is defining the **objective(s)** of the measures. In the case of eutrophication control, this may be to attenuate nuisance algal blooms or excessive growth of other plants, in order to protect the uses of the water. This may be the only objective. However, for waters of high conservation status, the long-term aim may be to develop or maintain a community characteristic of a less eutrophic state.

Defining chemical or ecological **targets** which will fulfil such objectives is a challenge, given the gaps in knowledge about cause and effect for some types of waters, particularly for flowing fresh waters and saline waters. Conventionally, the standards that have been used to underpin biological and chemical water quality have been concentrations of chemicals. In the short term this position is unlikely to change, since the development of ecological targets is less well advanced. However, as the emphasis of the proposed Water Framework Directive is on achieving good ecological quality, the present emphasis may shift towards ecological targets. While nutrients are not the only environmental variable that influences the eutrophication process, they are generally the key controlling factor and interim standards for phosphorus concentrations in fresh waters are proposed as follows.

5.5.1 Interim targets

Waters have for many years been classified into defined, though arbitrary, trophic states. These range from ultra-

oligotrophic (nutrient-poor and typically upland) through oligotrophic, mesotrophic and eutrophic to hypertrophic (extremely enriched and typically lowland). Attempts have been made to relate these descriptive trophic terms to specific 'boundary' values for certain water quality parameters. In 1982, the eutrophication control group of the Organisation for Economic Cooperation and Development (OECD) Cooperative Programme on Monitoring of Inland Waters published an internationally recognised set of class boundary values for total phosphorus (TP) in lakes (OECD, 1982). The annual geometric mean values given for the open trophic classification system in Table 1 are considered reliable for management purposes. This is because they are derived by a probabilistic approach which minimises the uncertainty of allocating a standing water to a given category. For example, a water body with an annual average TP concentration of 10 $\mu g\ l^{-1}$ would have a 10% chance of being ultra-oligotrophic, 63% of being oligotrophic, 26% of being mesotrophic and 1% of being eutrophic. This system also allows the specification of the level of probability (ie risk) which is considered acceptable: 80% confidence interval suggested by OECD offers a reasonable working reference. The Agency proposes the use of these values as interim targets for the control of eutrophication in standing fresh waters.

Table 1 Proposed interim standards for phosphorus in standing and running fresh waters.

Trophic category	Standing fresh waters (μg TP l^{-1}, annual geometric mean)	Running fresh waters (μg SRP l^{-1}, annual mean)
Oligotrophic	8	20
Mesotrophic	25	60
Meso-eutrophic	-	100
Eutrophic	85	200

TP = Total phosphorus; SRP = soluble reactive phosphorus.

With regard to rivers, the NRA, jointly with English Nature and Countryside Council for Wales, developed a set of 'Special Ecosystem' standards for soluble reactive phosphorus (SRP) in rivers of high conservation status. These standards were put forward to government in 1993 for consideration as part of the proposals for Statutory Water Quality Objectives (SWQOs). The SWQO scheme has not been applied except at pilot scale, and this trial did not include the phosphate standards. However, the Agency believes the Special Ecosystem phosphate standards for rivers to be the best available interim targets for use in eutrophication control, particularly for rivers of high conservation value, providing the relevant standards are selected with care at site-specific level. The proposed interim standards for phosphorus in standing and running fresh waters are shown in Table 1.

It is proposed that the above suites of national standards are applied with caution. The figures provided should be used as a guide but should not prevail over site-specific standards derived from a sound scientific understanding of a particular water body. In addition, the attainment of phosphorus targets is likely to bring ecological benefits only in cases where phosphorus is limiting, so the justification for action to control phosphorus should include evidence that phosphorus is, or could be made, a limiting factor. The use of 'hindcasting' techniques (see next sub-section) may assist in selecting achievable targets on a site-specific basis.

The above standards will also be useful in screening out actions that are unlikely to provide benefits. For example, in circumstances where using the full range of available nutrient control measures is unlikely to secure a concentration in the receiving water that is even close to the standard that has been adopted, then the case for control action will be poor unless there is other evidence of likely ecological improvements.

Quality objectives and standards for nutrients in estuarine and coastal waters are inadequately developed at present. It is expected that action on these waters will be linked to statutory drivers (see Section 5.6). The development of ecological quality objectives for coastal waters affected by eutrophication has been identified as an aim at international level, and will be considered as part of the OSPAR Strategy to Combat Eutrophication.

The Agency would welcome the opinion of others on the objectives for eutrophication control and the proposed interim targets for phosphorus in fresh waters.

5.5.2 Future targets

For the future, the Agency is investigating alternative and complementary approaches to the derivation of targets. Targets which take into account a 'reference' condition (ie the optimal chemical or biological quality that could be expected in a given water body) are considered a logical and appropriate way forward. The use of ecological targets, based on reference conditions, will be a requirement of the proposed EC Water Framework Directive, once scientific methods are sufficiently developed. Such reference conditions will need to be

derived for different geographical and climatic zones. For the Water Framework Directive, the division of Europe into different eco-regions and further division into ecotypes are being considered. In the United States (US), the Environmental Protection Agency (EPA) is intending to derive nutrient standards for different types of water bodies (lake and reservoirs, rivers and streams etc) for each of 14 eco-regions as part of a national strategy on nutrient enrichment and eutrophication (US EPA, 1998). Standards for the different reaches of rivers also need to be considered, since the physical nature of a river changes from its source to its mouth; this may lead to ecological targets for eroding and depositional reaches, perhaps defined through the stream order classification system.

In the shorter term, computer-based 'hindcasting' techniques can already be used to estimate the nutrient status of water-bodies before modern agricultural intensification (eg in the 1930s), and hence determine the degree of change that has taken place. This is achieved by considering natural catchment characteristics, eg morphology, geology and soil type, and historic records of land-use (modelling using nutrient export coefficients), or by the assessment of past diatom communities preserved in the lake sediment (palaeolimnology). The predicted 1930s baseline nutrient status provides a time-based 'reference' condition, to inform the consideration of appropriate targets, taking into account current land-use in the catchment and the technical, social and economic constraints. Used in conjunction with other information, this hindcasting is considered a potentially useful technique to assist in the selection of targets for standing and running fresh waters.

An alternative or complementary approach to the use of environmental targets is the application of source-orientated measures, based on minimising nutrient discharges/losses to waters, either generally or within the catchment of waters affected by eutrophication. This can be achieved through the use of load reduction targets, and/or the application of Best Available Techniques (BAT) to minimise nutrient inputs from discharges of urban waste water and Best Environmental Practice (BEP) to reduce nutrient losses from agriculture and forestry. This approach has been proposed for the purposes of the OSPAR Convention, as part of the strategy to address eutrophication problems in the North Sea. The adoption of a source-orientated approach may be useful in waters considered particularly sensitive to nutrient enrichment, where it is considered appropriate to apply the Precautionary Principle but where the current state of knowledge is insufficient to derive workable environmental objectives and targets.

Comments are invited on the potential application of a source-orientated approach, in accordance with the Precautionary Principle, in the absence of robust environmental targets and a clear understanding of cause and effect. Are there particular waters/circumstances to which such an approach should be applied?

5.6 Catchment-based action plans

5.6.1 Promoting a catchment-based approach

Eutrophication control at site-specific level is best addressed through catchment-based action plans. Waters will be identified for potential action on the basis of the criteria listed in section 5.4 and through Local Environment Agency Plans (LEAPs).

LEAPs are the Agency's main vehicle for identifying and prioritising local environmental issues and delivering targeted environmental improvements. Through the LEAP process, an assessment is made of the state of the local environment and the pressures placed upon it, and the public is consulted over proposed actions to address environmental problems. A catchment-based Action Plan is then drawn up and implemented through direct action by the Agency, through partnership with others, and by persuading other parties to take action. The success of the plan is reviewed annually, with a full review at the end of the five-year plan period. The development of LEAPs in the context of an overall framework for environmental management is a fundamental part of the Agency's new Environmental Strategy. The LEAP and Environmental Strategy disciplines enable the relative local importance of eutrophication issues to be balanced against other environmental priorities. In catchments where eutrophication is identified as a priority, the LEAP process could be extended, where appropriate, to develop a detailed more Eutrophication Control Action Plan (ECAP).

Where the dominant cause of a local eutrophication problem is readily identifiable and controllable by regulatory means, for example a large sewage effluent discharge, there is unlikely to be a need for a detailed ECAP. However, where different (particularly diffuse) sources of nutrients contribute to eutrophication and a number of water uses are affected, the solutions are more complex. There are likely to be considerable challenges in balancing the views of the various interested parties (eg regulators, dischargers, farmers, water users) and in deciding and implementing appropriate control actions. In these situations, the setting up of a community group, similar to

the Total Catchment Management (TCM) Committees established to tackle eutrophication problems in Australia, is considered a promising approach. Where appropriate, ECAPs could be progressed through such community groups, with the Agency providing a facilitator to ensure appropriate support, data and guidance for the process.

In formulating an ECAP, it will be necessary to identify the key sources of nutrients within the catchment and assess their relative contributions. An understanding of the mechanisms of delivery of nutrients to waters, the internal processes within the water body and the influence of other factors on the ecological expression of eutrophication is also required. With this information, and taking into account the objectives and targets, it is possible to assess options for reducing nutrient inputs (through source or transport control), and determine other management actions which may be necessary to control eutrophication. Consideration of costs, benefits and environmental risks will help to identify the most effective and sustainable solutions. The best mechanisms for implementing the ECAP must also be identified, be they mandatory (making best use of the regulatory framework), voluntary (consultative, collaborative and community-based), financially or technically assisted, or a combination of these types of approach. A framework for monitoring progress is also required.

The Agency invites views on the need to manage the risks and impacts of eutrophication at the local level through a mix of regulatory and other mechanisms (voluntary, collaborative and educational). In particular, comments on the establishment of community groups as a means of addressing local problems would be welcomed.

Pilot ECAPs are being developed, in the first instance for selected standing waters, to determine what can be achieved and guide further refinement of procedures. An example is the ECAP for Bittell Reservoirs (Worcestershire), aimed at controlling blue-green algal problems. This plan is based on the TCM model and has progressed well to date. The Agency is also looking to learn from experiences in other parts of the UK (Loch Leven, Loughs Erne and Neagh) and beyond, where action plans to control eutrophication are being pursued.

The schedule for ECAP development and implementation will be driven primarily by deadlines relating to relevant statutes and international commitments (eg UWWT Directive, UK Biodiversity Action Plan), and by the timetable for the completion and review of LEAPs. As discussed in Section 4.2.2, in the medium term, the proposed EC Water Framework Directive, once adopted, will become a key driver of water quality improvements. The timescales in the final Directive are likely to have a significant bearing on the deadlines for the delivery of ECAPs. In the absence of statutory drivers, the pace of implementation will depend to a great extent on the degree to which the parties involved can reach a consensus regarding appropriate action. It will be necessary to balance the case for a precautionary approach against the risks of failure to deliver benefits in cases where the scientific understanding of the system is poor.

ECAPs can potentially be developed for all types of environmental surface waters. However, the ECAP/TCM approach is considered best suited to the control of eutrophication in freshwater situations. Compared to the position for saline waters, the catchments of fresh waters are generally of a more manageable size and phosphorus is normally the limiting nutrient. In saline waters, nitrogen is often the limiting nutrient and, unlike phosphorus, nitrate loss from agricultural land generally occurs on a catchment-wide basis (excess nitrate being readily leached and transported to waters). Statutory initiatives, to reduce nitrate leaching from agriculture and nitrogen inputs from STWs (generally the two main sources of nitrogen) in affected catchments, exist in the form of the EC Nitrate and UWWT Directives. Where estuarine waters are identified as affected by eutrophication, the application of these statutory measures, on a catchment basis, is considered the most appropriate mechanism for control. With regard to coastal waters, issues of scale dictate that international management regimes such as the OSPAR Convention and relevant EC Directives become the appropriate vehicle for the identification and control of problems.

5.6.2 The tools required for the development of Eutrophication Control Action Plans

The Agency is drawing together details of the best available methods, models, techniques and procedures for use in the development of ECAPs. The intention is to provide a 'toolkit' to facilitate the various tasks involved in formulating and implementing a plan. The requirements can be broken down into the following main areas.

i. Methods and criteria for assessing or predicting the impacts of eutrophication (discussed in Section 5.3).

ii. Methods for identifying key sources of nutrients in a catchment, and assessing their relative contributions.

iii. Tools and models for predicting the processes which occur within water bodies, involving nutrients, the biota and the influence of other factors on the biological expression of eutrophication.

iv. Methods for assessing the costs and benefits of management options.

v. Mechanisms for consultation/collaboration and implementation (discussed in Section 5.6.1).

vi. Practical considerations of eutrophication control techniques, including environmental impact assessment.

vii. A framework for monitoring and reviewing progress once implementation has begun.

The state of development of tools in relation to each of the above requirements is highly variable and, for items **(i)** and **(iii)** in particular, varies significantly between the different types of surface waters (standing fresh waters, running fresh waters, estuaries and coastal waters). Scientific understanding of the ecological processes **(iii)**, and hence the ability to model the system and predict the effect of management actions, is considered to be well developed for standing fresh waters, less so for running fresh waters and poorest for saline water ecosystems. The Agency believes that existing models, such as PACGAP (Prediction of Algal Community Growth And Production) and PROTECH (Phytoplankton RespOnse To Environmental Change), for assessing the biological response to nutrients and other factors in standing fresh waters (and slow flowing rivers), are adequate for assessing management options. For rivers and estuaries, existing models are generally over-simplistic (assuming conservative behaviour of nutrients) or too 'data-hungry' for routine application, although promising research and development (R&D) in this area is now in progress.

As regards **(ii)**, quantifying point source inputs of nutrients to a catchment is relatively straightforward. For the quantification of diffuse nutrient inputs from agricultural sources, the Agency believes that export co-efficient modelling currently offers the most promise as a workable approach. This enables estimates to be derived of the relative contributions of nutrients to a catchment from different types of land use and also from livestock, human and atmospheric sources. More detailed process-based models are considered to be insufficiently developed and too data-intensive for routine use at present, although considerable investment in R&D internationally will improve this position with time.

With regard to the consideration of costs and benefits **(iv)** the Agency is gaining experience from the assessment of priorities for water industry expenditure, under the Asset Management Planning (AMP) process by which water prices are determined. With respect to eutrophication control methods in particular, some work on cost-benefit analysis has been completed, although the environmental benefits are extremely difficult to cost and quantify.

The issue of practical eutrophication control techniques and their efficacy **(vi)** is a major topic in its own right and the subject of many books, papers and ongoing R&D. A brief overview is given in Section 5.7.

On **(vii)**, the Agency has considerable experience of implementing and monitoring the progress of environmental improvement plans, from its LEAPs process and other operational activities.

The Agency welcomes views on the tools proposed for use in the formulation and implementation of action plans.

5.7 The broad options for eutrophication control

If nutrients are identified as the key factor controlling eutrophication in a water body, the main external and internal sources must be identified and their relative contributions assessed. This may lead to the implementation of one, or several, control options.

The direct control of external nutrient sources might include any of the following measures.

- Removal of nutrients from sewage effluents and relevant industrial discharges by installing chemical or biological treatment processes, or artificial wetlands.

- Targeted farm advisory visits, in which critical source areas for nutrient losses are identified, and nutrient and waste management plans are drawn

up to ensure that all on-farm nutrient resources are used efficiently. Farmers should also be advised on best practice (including environmental audits) and be encouraged to adhere to codes of good agricultural practice. In some circumstances, land use or land management changes (eg buffer zones) may be appropriate.

- Control of effluent from septic tanks in sensitive rural catchments.

- Treatment of fish farm effluents (eg through the use of drum filters), and discouraging the damaging and non-sustainable practice of manuring controlled waters to enhance fish growth.

- Controlling atmospheric emissions of ammonia and/or oxides of nitrogen from industrial, vehicular and agricultural sources. However, such controls are likely to be driven by national and international commitments rather than by local eutrophication problems.

- Treatment of urban and highway run-off through the use of retention ponds, artificial wetlands and other biological nutrient traps.

In situations where the immediate receiving water does not suffer from eutrophication but delivers nutrients to a more sensitive water downstream, any of the following methods could be considered.

- Physical treatment of small, nutrient-rich tributaries (flocculation/filtration), or their diversion to a less sensitive receiving water.

- Creation of detention basins or wetlands at the inflow point, to encourage sedimentation or the growth of plants or algae which can subsequently be removed.

- The engineering of rivers (for example, the introduction of meanders) and encouragement of in-stream vegetation, to increase the retention and uptake of nutrients.

Control of internal nutrient loadings can also form an important step in the restoration of waters affected by eutrophication. Potential control measures include:

- Flushing or diluting with low nutrient water (washout).

- Treating with iron or aluminium salts.

- Aerating the lower layers of a stratified water to limit the release of phosphorus from the sediments, or selectively removing water from these layers if it becomes enriched.

- Removing nutrient-rich sediments by suction dredging, or by isolating them from the overlying water using plastic covers (sediment sealing).

- Removing fish species such as carp and bream which disturb sediments, causing the release of nutrients, or birds which add nutrient-rich faeces to the water (guanotrophy).

- Removing nutrients by harvesting the biomass.

Finally, there are immediate measures to control algae or other aquatic plants once they have developed. These potentially include:

- The corralling (containment) and removal of algal scums.

- De-stratification, which induces movement within water bodies, reducing the time that algae can spend in the light zone, and so disrupting the formation of blooms.

- The application of aquatic herbicides, algicides or barley straw, which has been shown to inhibit the growth of algae. (The use of chemicals should generally be limited to ornamental lakes and ponds, or situations where other methods are unlikely to be effective. Chemicals should only be used by trained operators, and only in conjunction with MAFF and Agency guidance and product instructions. The use of barley straw should be carefully monitored, due to uncertainties about the nature of the active ingredient).

- Weed-cutting and removal.

- Biomanipulation techniques, which alter the fish community in order to increase the numbers of grazer zooplankton. Reductions in phytoplankton communities are achieved by removing zooplanktivorous fish (such as carp, roach and

bream) and/or through the introduction of predatory fish (such as pike) which themselves reduce the population of zooplanktivorous fish.

All of these options carry costs and some of them also have associated environmental risks which will need to be assessed when considering potential control measures. Where these dictate that the prevention or treatment of blue-green algal blooms cannot be achieved, the existing policy of monitoring and warning water owners and users of the problem will be followed in the long term. In other cases, this policy may be an interim measure while a Eutrophication Control Action Plan is developed and implemented.

Whether or not positive controls are implemented, it is important that actions which could increase the risk of deleterious change are avoided wherever possible. These actions are most likely to be an issue in small, shallow lakes that are rich in nutrients but do not necessarily suffer from algal problems, and include:

- Substantial weed removal, which can reduce nutrient buffering capacity and destroy the habitat of grazing zooplankton, exposing them to increased fish predation and reducing their capacity to control algal populations.

- Altering the balance of the fish community in favour of bottom feeders (eg carp and bream) which stir up sediments thereby releasing nutrients into the water, or zooplanktivorous fish (such as roach), or by significant removal of predatory (piscivorous) fish thereby increasing populations of species such as carp, roach and bream.

5.8 Research and Development

It is important that policy development is underpinned by sound science as far as possible. Although eutrophication-related R&D has received substantial investment by the international community in recent decades, our understanding of the processes involved is not yet complete. This is particularly the case in relation to eutrophication in running fresh waters and saline waters and mechanisms which deliver diffuse nutrients to environmental waters.

The Agency will therefore continue to fund targeted R&D into aspects of eutrophication and its control. It is in the process of reviewing the current state of knowledge and identifying priority areas for further attention. Forging links with other parties involved in such research, within the UK and abroad, will remain important, in order to learn from the work of others and identify opportunities, where appropriate, for collaborative projects.

The Agency is also keen to work with government departments and other organisations to ensure that the findings of sound R&D are fed through, at the earliest opportunity, into the development of policies and guidance on best practice. An important area, in this respect, is that of phosphorus loss from agriculture. Control of such losses will require appropriate guidance on best management practices, identification of critical source areas, nutrient management planning and land management. MAFF and WOAD have recently published new versions of the Codes of Good Agricultural Practice for the Protection of Water and Soil (MAFF/WOAD, 1998a, 1998b). The original codes (MAFF/WOAD 1991, 1993) lacked guidance on the issue of phosphorus loss, but this has been addressed in the new Codes.

Another important area of R&D is climate change. This will reduce the amount of water in rivers and groundwater, particularly in south-east England, and may therefore exacerbate potential eutrophication problems. Along with others, the Agency is investing in R&D to predict the effects of this global issue. It is also working to reduce emissions of greenhouse gases, through regulatory controls. The proposed Water Framework Directive should provide a mechanism by which the effects of climate change on eutrophication can ultimately be managed.

6. CONCLUSION AND NEXT STEPS

This document has outlined the risks and impacts associated with aquatic eutrophication in England and Wales and discussed the need for a strategy to deal with this specific environmental issue, within the context of the Agency's overall Environmental Strategy. The key elements of the proposed strategy for managing eutrophication have been described.

The Agency would like to receive views and suggestions on any of the issues raised in this consultation document. **A list of the main points for discussion, and the consultation arrangements, in Section 10.**

Following consultation on the basic principles and framework for the management of eutrophication, as set out in this document, the logical next steps would be:

- to consider the response to the consultation;

- to meet with relevant government departments, other regulators and other key organisations to discuss the outcome of the consultation and the way forward;

- to draw up an implementation plan comprising a framework for dealing with:
  - priorities and timescales for delivery of actions;
  - internal procedures for implementing the strategy;
  - external communication and collaboration needs;
  - services required (monitoring, modelling etc);
  - costs and funding sources; and
  - research and development needs;

- to publish final details of the Agency's strategy;

- to implement the strategy progressively in phases, in collaboration with others; and

- to review progress and modify the approach as necessary.

7. ACRONYMS

CEFAS	Centre for Environment, Fisheries and Aquaculture Science
DO	Dissolved oxygen
DoE	Department of the Environment
EC	European Community
ECAP	Eutrophication Control Action Plan
EFTA	European Free Trade Association
EHO	Environmental Health Officer
EPA	Environmental Protection Agency
EU	European Union
GQA	General Quality Assessment
JoNuS	Joint Nutrient Study
LEAP	Local Environment Agency Plan
MAFF	Ministry of Agriculture, Fisheries and Food
N	Nitrogen
NRA	National Rivers Authority
NVZ	Nitrate Vulnerable Zone
OECD	Organisation for Economic Cooperation and Development
OSPAR	Oslo and Paris Convention
P	Phosphorus
pe	Population equivalent
R&D	Research and Development
SAC	Special Area of Conservation
SPA	Special Protection Area
SRP	Soluble Reactive Phosphate
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
SWQO	Statutory Water Quality Objective
TCM	Total Catchment Management
TP	Total Phosphorus
UK	United Kingdom
US	United States
UWWT	Urban Waste Water Treatment
WPZ	Water Protection Zone

8. GLOSSARY

Algae	General term applied to photosynthetic organisms that are generally aquatic, may be microscopic or very large (eg seaweeds), and may be floating or attached.
Algal bloom	Surface scums of algae in fresh and saline waters which accumulate under calm weather conditions from populations that were previously distributed throughout the water. Decomposing dead cells consume large quantities of oxygen in the water which may result in the waters becoming anaerobic. Some blooms may produce toxins.
Artificial wetland	A low-lying area of marsh land, constructed and managed so that it traps, and potentially breaks down, certain pollutants, and/or provides desired habitat types.
Asset Management	Water Companies' Strategic Business Plans - initiated by the Office of Water Services (OFWAT) as part of the periodic review of water company charges.
Benthic	Associated with the bed of a waterbody.
Biodiversity	(Biological diversity) - the variety of life, as indicated by the number of species present.
Biomanipulation	Deliberate alteration of the biological community to achieve a desirable and planned change in environmental conditions.
Biomass	Total quantity or weight of organisms in a given area or volume - eg algal biomass.
Blue-green algae (cyanobacteria)	Group of largely microscopic, photosynthetic organisms with a bacterial structure, but containing chlorophyll a and a photosynthetic biochemistry unlike other bacteria but similar to that of other algae and higher plants.
Buffer zone	Area of natural, semi-natural or uncultivated vegetation bordering a waterbody which is managed to intercept and trap certain diffuse pollutants, and/or to provide desired habitat types.
Catchment	Area drained by a river or a river system.

Chlorophyll a The major photosynthetic pigment of algae and plants.

Codes of Good Agricultural Practice A set of three codes, produced by MAFF and WOAD, giving practical guidance, that helps farmers to avoid causing water, soil or air pollution.

Competent authority A government or other agency designated to carry responsibilities during the implementation or enforcement of specific legislation.

Consent A statutory document issued by the Agency which defines the legal limits and conditions on the discharge of an effluent to a watercourse.

Controlled waters All rivers, canals, lakes, groundwaters, estuaries and coastal waters to three nautical miles from the shore, even where beds or channels may be dry at certain times of the year.

De-stratification Process of mixing, or inducing circulation, in a waterbody that might otherwise settle into layers of different water quality. During calm summer periods, this artificial turbulence reduces the time which planktonic algae can spend in the well-illuminated, upper part of the water column, and so inhibits their ability to form blooms.

Diatom Group of brown or yellow-coloured algae commonly found in natural waters. The cell wall is made of polymerised silicate which is readily preserved in sediments when the organic part of the organism decays.

Diffuse source Supplies of nutrients or other pollutants that come from a myriad of small-sized locations.

Directive Legislation issued by the European Community which requires a Member State to implement its requirements, for example to achieve specified environmental standards.

Economic instruments Measures, such as charges and taxes, which place a 'price' on the effects of polluting activities, and thereby force the polluter to consider the costs.

English Nature Statutory body responsible for nature conservation in England.

Environmental waters In this context a term meaning standing freshwaters, running freshwaters, estuaries and coastal waters.

Equilibrium Phosphorus Concentration The concentration of dissolved orthophosphate (equated to Soluble Reactive Phosphorus) in solution after 24 hours in contact with suspended sediment/soil in well-mixed conditions.

Eutrophic A description of water which is rich in nutrients and is highly productive.

Eutrophication The enrichment of water, by inorganic plant nutrients, which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants, affecting the quality of the water and disturbing the balance of organisms present within it. Such changes may be undesirable and interfere with water uses.

Eutrophication Control Action Plan A plan which aims to provide the best option for controlling a eutrophication problem in a particular catchment where this is identified as a priority issue through the LEAPs process.

Export co-efficient model Technique for calculating nutrient loadings and concentrations in a stream or lake from a knowledge of land use, numbers of stock and number of people in the catchment, stream discharge and the rates at which the nutrients are leached or excreted from the various sources.

General Quality Assessment (GQA) The Agency's method of placing waters in categories according to assessments of different aspects ('windows') of water quality. The scheme provides a means of assessing and reporting environmental water quality in a nationally consistent and objective way.

Hindcasting The process of estimating the state of a waterbody at a given point in the past, in the absence of appropriate baseline water quality data. This is achieved by considering natural catchment characteristics eg morphology, geology and soil type, and historic records of land-use, or by the assessment of past diatom communities preserved in the lake sediment.

Hypertrophic A description of water which is extremely nutrient-enriched, and typically affected by heavy growth of algae and other water plants.

Invertebrates Animals which lack a vertebral column (backbone) - used for biological classification. Especially aquatic macro-invertebrates (animals of sufficient size to be retained in a net with a specified mesh size).

Lake classification scheme A proposed scheme for the classification of standing waters in England and Wales, based on chemical, biological and hydrological variables. Waters can be classified using a state-changed system comparing current status against an earlier baseline quality, or a spatial state system to allow comparison between lakes.

Limiting nutrient Nutrient in an ecosystem which is in short supply relative to demand, and can thus inhibit efficient and productive ecological development.

Local Environment Agency Plan The process by which the Agency plans to meet all the environmental issues in a catchment. A consultation plan is published, followed by an action plan which is reviewed at five-year intervals.

Macrophyte Any plants large enough to be seen with the naked eye, including all higher aquatic plants, together with some algal species.

Mesotrophic A description of water which is of medium nutrient status and medium biological productivity (between oligotrophic and eutrophic).

Nitrate Sensitive Area An area which gives rise to nitrate concentrations in sources of public drinking water which exceed, or are at risk of exceeding a limit of 50 mg l^{-1}, laid down in the 1980 EC Drinking Water Directive, and where voluntary, compensated agricultural measures were introduced in 1990 as a means of reducing those levels.

Nitrate Vulnerable Zone An area where nitrate concentrations in sources of public drinking water exceed, or are at risk of exceeding the limit of 50 mg l^{-1} laid down in the 1991 EC Nitrates Directive, and where compulsory, uncompensated agricultural measures can be introduced as a means of reducing those levels.

Nutrient Substance providing nourishment for plants (or animals) eg nitrogen, phosphorus, silicon, potassium, etc.

Nutrient export coefficient A measure of the nutrient loss from a specific land use, typically measured as kg ha^{-1} yr^{-1}.

Nutrient Management Plan (NMP) A plan, often resulting from on-farm nutrient budget calculations and environmental audits, to ensure that the nutrients supplied to a crop, from the soil reserve, chemical fertilizers, manures and other wastes, closely match the need of that crop. Minimising the surplus reduces nutrient losses to water.

Oligotrophic A description of water which has a low nutrient status and low biological productivity.

Orthophosphate A fraction of phosphorus, often approximately equated to Soluble Reactive Phosphorus, as measured by the molybdenum blue assay on a filtered sample. (If the determination is carried out on an unfiltered sample, the fraction measured is Total Reactive Phosphorus).

Oslo Convention The Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (1972).

OSPARCOM The OSlo and PARis COMmissions, established to administer the Oslo and Paris Conventions for the prevention of marine pollution.

Paris Convention The Convention for the Prevention of Pollution from Land-based Sources, signed in Paris (1974), which addresses the problems of toxicity, persistence and bio-accumulation of certain pollutants entering the marine environment. It was extended to include airborne pollution in 1987.

Partnership approach Cooperation and collaboration between the Agency, its customers and all relevant sectors of society in order to achieve a coherent and consistent framework for environmental protection and enhancement.

Phytoplankton Community of largely microscopic algae suspended or floating in natural waters. Most species are denser than water and tend to sink, but are maintained in suspension by wind-generated water currents.

Piscivore Animal that eats fish.

Point source Supplies of nutrients or other pollutants that come from discrete, identifiable, comparatively large origins (eg sewage treatment works).

Population equivalent (pe) A single population equivalent is the organic biodegradable load having a five day Biochemical Oxygen Demand (BOD) of 60g of oxygen per day (nominally equivalent to the load from a single person's domestic waste).

Precautionary principle The principle that even when the (exact) effect, or even whether there is any effect, of a potentially harmful emission or discharge into the environment is not known, a presumption exists against its release.

Primary treatment The physical treatment of sewage effluent, usually settlement, to remove gross solids and reduce suspended solids by about 50 per cent and biological oxygen demand (BOD) by about 20 per cent.

Pristine state Nature of an ecosystem that is not influenced by any human activity, or at least by technologically sophisticated activity.

Qualifying discharge The effluent from a sewage treatment works serving greater than 10,000 pe, which discharges directly, or indirectly, into a Sensitive Area, and therefore, under the terms of the Urban Waste Water Treatment Directive, may require better than secondary treatment (eg nutrient removal).

Risk assessment A technique for evaluating the likelihood of a potential hazard being realised, considering both the probability of the occurrence, and the extent of the damage that could result.

Scum The surface debris that can result from blooms of algae and other plants.

Secondary treatment Biological treatment and secondary settlement of sewage effluent, normally following primary treatment, capable of producing a substantial reduction in biological oxygen demand (BOD) and suspended solids. This process may also involve some chemical and physical treatment.

Sensitive Area (eutrophic) UK Government designation under the Urban Waste Water Treatment Directive of a water which is affected, or at risk of becoming affected, by eutrophication, and which receives a qualifying discharge.

Site of Special Scientific Interest (SSSI) An area given a statutory designation by English Nature or the Countryside Council for Wales because it is particularly important, on account of its nature conservation value.

Special Ecosystem Class A proposed classification system relating to SSSIs and other rivers of high conservation value, which formed part of the NRA's proposals for Statutory Water Quality Objectives. The system incorporates river quality standards for phosphate concentrations.

Statutory driver A specific piece of domestic or European legislation, or an international commitment, which requires some form of control action to be taken.

Statutory Water Quality Objectives Use-related water quality targets for individual stretches of water, that have been given statutory force through the issue of Regulations by the Secretary of State under the Water Resources Act 1991.

Stream order classification Hierarchical classification of streams and rivers based on the magnitude of their channels and position in a drainage area.

Sustainable development Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Total Phosphorus The sum of dissolved and particulate phosphorus fractions.

Trophic state The category of a water in relation to the process of eutrophication, typically assessed on the basis of nutrient and chlorophyll concentrations, and transparency. Waters have traditionally been classified into five trophic states: ultra-oligotrophic, oligotrophic, mesotrophic, eutrophic and hypertrophic (see individual definitions).

UK Biodiversity Action Plan A plan produced on behalf of the government by the UK Biodiversity Steering Group in response to the signing of the Convention on Biological Diversity in 1992 (at the United Nations Conference on Environment and Development or 'Earth Summit'). The plan provides a framework for the conservation and enhancement of biological diversity within the UK, and for contributing to the conservation of global diversity through all appropriate mechanisms.

Ultra-oligotrophic A description of water with extremely low nutrient availability for the growth of algae or other plants (sometimes referred to as dystrophic).

Water Protection Zone (WPZ) A zone designated by the Secretary of State under the provisions of the Water Resources Act 1991, with a view to controlling pollution, or restricting potentially polluting activities in that area.

Zooplankton Animal community that is free-swimming or suspended in the open water.

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10. CONSULTATION ARRANGEMENTS

The Agency is keen to receive feedback on the proposed strategy and would welcome views and observations on any of the issues discussed in this consultation document. We would particularly welcome comments on:

- the perceived importance of eutrophication as an environmental problem in different types of environmental waters (standing fresh waters, running fresh waters, estuaries and coastal waters), and the proposals for raising awareness (Sections 2.5 and 5.1);
- the intention to promote a partnership approach to the management of eutrophication, both at local and national level (Section 5.2);
- the need to manage the risks and impacts of eutrophication through a mix of regulatory and other (voluntary, collaborative, educational and economic) mechanisms (Sections 4, 5.2 and 5.6.1);
- the merits of economic instruments and agri-environment incentive schemes as potential mechanisms for reducing agricultural nutrient losses (Sections 4.2.3 and 5.2.2).
- the proposal to review arrangements for assessing the extent of eutrophication in different types of environmental waters (Section 5.3);
- the prioritisation of waters for management action and the pace of implementation (Sections 5.4 and 5.6.1);
- the objectives for eutrophication control and the proposed interim targets for phosphorus in fresh waters (Section 5.5);
- the circumstances in which a source-orientated approach should be adopted, in accordance with the precautionary principle, in the absence of robust environmental targets and a clear understanding of cause and effect (Section 5.5.2);
- the proposal to manage eutrophication at site-specific level through the development of catchment-based action plans within the context of a national framework (Sections 4.3 and 5.6);
- the tools available for use in the formulation and implementation of action plans (Section 5.6.2).

Responses to this consultation should be sent by 28 February 1999, to Simon Leaf, Nutrients Manager, The Environment Agency, Ecotoxicology and Hazardous Substances National Centre, Evenlode House, Howbery Park, Wallingford, Oxon OX10 8BD. Respondents should explain who they are and whom they represent. Please note that comments submitted will be made available for public scrutiny unless they are expressly identified as confidential and to be treated as such. It is intended that a national seminar will be held towards the end of the consultation period, in order to provide the opportunity for further comments and discussion. The Agency intends to publish a final version of the strategy by early summer 1999.

This document is also available on the Environment Agency Internet site.
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