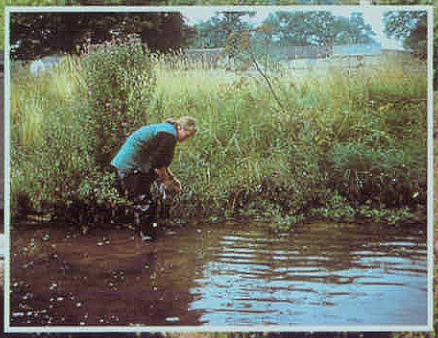
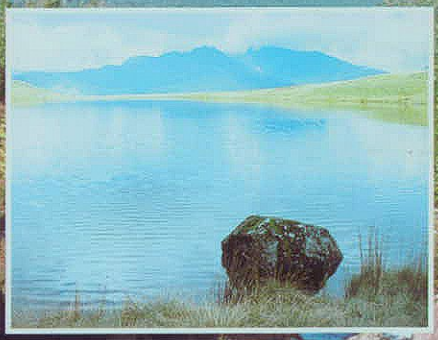
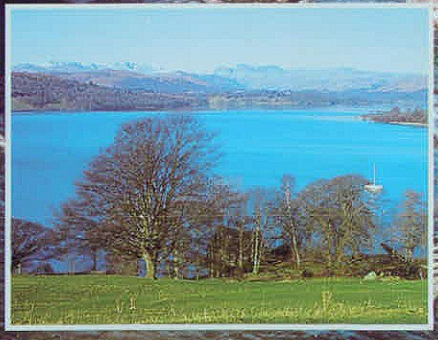
The United Kingdom Environmental Change Network

Protocols for Standard Measurements at Freshwater Sites







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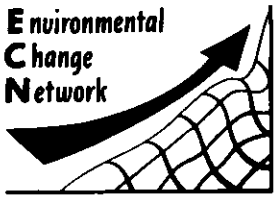

The United Kingdom Environmental Change Network:

Protocols for Standard Measurements at Freshwater Sites

Edited by
J. M. Sykes, A. M. J. Lane and D. G. George

Centre for Ecology & Hydrology
Natural Environment Research Council

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The **Environmental Change Network** is co-ordinated and managed by the Natural Environment Research Council, on behalf of the sponsoring organisations:

Biotechnology & Biological Sciences Research Council
Countryside Council for Wales
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English Nature
Environment Agency
Forestry Commission
Defence Evaluation & Research Agency (Ministry of Defence)
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Natural Environment Research Council
Scottish Environment Protection Agency
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The ECN Central Co-ordination Unit is based at the Institute of Terrestrial Ecology's Merlewood Research Station. ITE is a component research organisation within the Natural Environment Research Council, and is part of the Centre for Ecology and Hydrology (CEH).

CEH comprises four Institutes
- Institute of Freshwater Ecology
- Institute of Hydrology
- Institute of Terrestrial Ecology
- Institute of Virology and Environmental Microbiology

Cover photographs are as follows: Background picture – Allt a' Mharcaidh, Highland Region, Scotland. Provided by Don Monteith, Acid Waters Monitoring Network. Top left inset – River Lathkill, Derbyshire, England. Provided by the Environment Agency, Midlands Region. Top right inset – Llyn Llagi, Snowdonia, Wales. Provided by Don Monteith, Acid Waters Monitoring Network. Bottom left inset – Lough Neagh, Northern Ireland. Provided by the Department of Agriculture for Northern Ireland. Bottom right inset – Windermere, Cumbria, England. Provided by the Institute of Freshwater Ecology.

Dr T. W. Parr
ECN Central Co-ordination Unit
Institute of Terrestrial Ecology (NERC)
Merlewood Research Station
Grange-over-Sands, Cumbria LA11 6JU
Tel: 015395 32264; Fax: 015395 34705
Email: ECNCCU@ite.ac.uk
WWW: http://www.nmw.ac.uk/ecn

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PREFACE

ECN in retrospect and in prospect: freshwaters

This is the second volume of protocols used in the United Kingdom Environmental Change Network (ECN). Since the publication of the first, on terrestrial protocols (Sykes & Lane 1996), ECN has continued to evolve and has grown stronger through experience. However, it is still useful to look back at its early stages, the rationale and context, and to look forward – what are the trends and challenges?

Evolution of ECN

The need for long-term ecological information was recognised within the Natural Environment Research Council (NERC) in its review of 'Biological Surveillance' in marine, freshwater and terrestrial environments in the 1970s (NERC 1976). The Working Parties which carried out the review considered that:

> "Surveillance implies not only measurement and detection of change but also its understanding and interpretation and the development of a capacity for predicting likely future change. It cannot be considered in isolation but must be accompanied by physical and chemical observation and by basic ecological and physiological research".

This overall view (which included survey as well as monitoring) and many of the current features of ECN were envisaged by the Working Parties. The main recommendations of the review were limited:

- establish a standing committee to review progress;
- consider co-ordination;
- organise seminars every 3–5 years.

However the Freshwater Working Party envisaged a central co-ordinating group supported jointly by NERC, the Department of the Environment (DOE, now part of the Department of the Environment, Transport and the Regions (DETR)) and the National Water Council, whilst the Terrestrial Working Party recommended that existing surveillance schemes be "encouraged to use common sites" and that "a network might later be developed from these sites." In practice, many of the features subsequently incorporated into ECN were envisaged in the 1976 report; it just took time!

Monitoring was an unfashionable word in the 1980s. It was associated with routine, unscientific observations which contributed little to the understanding of environmental change. In many cases it was independent of research designed to determine causal

relationships and to predict future conditions. Recognition of the lack of long-term information on the state of our environment which is rigorous, comprehensive and quantitative has come to the fore, precipitated by concerns such as loss of biodiversity, widespread pollution and predictions of climate change. The critical observations of stratospheric ozone and atmospheric carbon dioxide levels, obtained through the persistence of individual scientists, added great weight to the argument for sustained long-term observations.

The need for data on long-term change was the major motivating force behind the formation of ECN. A further key factor was the recognition that many different organisations, for very different reasons, have well-established field stations or sites at which independent observations and experiments were being made. Could the various organisations collaborate to provide sites which, together, would form a national network capable of sampling the main UK environments with minimal costs? Could adaptation and co-ordination of existing observations provide an integrated monitoring system which would detect and lead to an understanding of change? Could the links between research and monitoring be strengthened by use of sites for both purposes? These questions were addressed by an inter-agency Working Group led by NERC in 1988–89, resulting, finally, in the establishment of ECN in 1992.

A key principle, which was central to ECN from its inception, was the concept of integrated monitoring. Many projects are concerned with detecting long-term change in particular aspects of the environment (eg water quality, acid rain, or ozone) or with particular groups of organisms (eg fish, plankton or macrophytes), or with particular processes (eg greenhouse gas emission or sedimentation). However, these represent only parts of the environment and its component ecosystems. Integrated monitoring is the measurement of related biotic and abiotic components, co-ordinated in time and "When based on an interconnected picture of the environment and the biosphere (through the notion of biogeochemical cycling of trace substances, for example), the monitoring system is likely to be much more responsive to detecting surprises than if it consisted of several disconnected components (an air monitoring network; a water quality network, etc)." Such integrated (or multimedia) systems have been planned for various sites and networks (eg Santolucito 1991). However, the only comprehensive network in which the concept has been implemented is the Integrated Monitoring Programme of the United Nations Economic Commission for Europe (UN-ECE 1993) which focused on forest catchments, recognising the interaction between terrestrial and freshwater systems.

In ECN the initial concentration on terrestrial sites was successful in getting agreement between nine government departments and

agencies to support the co-ordinated measurements at their individual sites, and to contribute the data to a central database funded mainly by NERC. This major achievement has been followed by the expansion of the network into freshwater sites, now numbering 42 (26 rivers, 16 lakes) supported by six agencies. The larger number of freshwater sites, as compared with terrestrial sites (now 12) reflects the prior existence of more long-term monitoring programmes at freshwater sites. For example ECN is able to make use of sites from programmes sponsored by the DETR, *viz.* the 'Harmonised Monitoring Scheme' network established in 1974, and the 'Acid Waters Monitoring Network' established in 1988.

The establishment of the network of sites is one step; defining the variables and measurement methods needed to cover the range of system components is another matter. This has required considerable effort by members of the ECN Freshwater Working Group, in consultation with many other scientists. The existing experience of monitoring accrued by the water authorities, and focused mainly on measurement of physical and chemical variables using well-standardised methods and quality control, has been of considerable value. The options for monitoring biological variables or indicators are much greater and it has been necessary to make compromises in the final selection of measurements to make feasible the operation of the network. However, there is a clear logic in the selection of interconnected driving, state, and response variables which will allow testing of relationships. Selection problems were addressed by drawing on the experience of sectoral monitoring programmes, on the breadth of ecological knowledge available to the ECN Freshwater Working Group, and from schemes such as RIVPACs (Wright *et al.* 1993) which allows the state of the water and its biological community to be indicated through analysis of its invertebrate composition.

Future developments

The measurements are now in progress, a comprehensive data set is beginning to accumulate across the network, and quality control systems are in place. The publication of these freshwater protocols, following those published for terrestrial sites, is part of the process of data quality assurance and is designed to provide detailed, citable background information for anyone using ECN data. It also increases the opportunity for a wider debate on the technology of integrated monitoring, as well as providing assistance to others who may be setting up monitoring networks.

ECN has come a long way since the planting of ideas in 1976, their germination in 1986, and the establishment of the network in 1992. It is now in what an ecologist would regard as the early stages of succession. What of the future? We know that the

system is not perfect, but it has already shown the essential capacity to evolve. Some of the adaptations which are likely to occur are:

- a period of stability allowing accumulation of sufficient data to test the value of individual variables and to compare responses across the network;
- testing of a few other variables for possible addition to the suite of observations, although options for expansion are limited by support costs;
- a small and gradual increase in the number of terrestrial sites to improve the environmental and land use coverage of the network;
- increased interaction with sectoral monitoring projects which provide for wider geographical assessment of changes in individual components;
- further analysis of past data from individual sites to enhance the time series, define variability, and explore responses to environmental variation;
- enhancing the links between the freshwater and terrestrial components of ECN;
- development of a 'rapid response procedure' to capitalise on the existence of the network in the event of extreme environmental events;
- focusing results from national research programmes, possibly as scenarios, to provide hypotheses and test the distribution of changes that are occurring or likely to occur across the network;
- increased connection with European and global monitoring systems.

The individual sites and their operation are the critical pieces of the ECN jigsaw (it is the capabilities and dedication of the site researchers on which the network depends – but it is the information from the network as a whole which is the instrument for detection of change). One of the most important capacities of the network is to explore the extent to which changes detected at one site are observed at others; are the changes national, regional or merely local? It is here that the links with other networks and research programmes have great potential.

Thus ECN is only part of the system needed to detect and understand environmental change and its consequences in the UK. It represents the intensive, fine-scale level of resolution at which variables are measured continuously or at short time intervals. This identifies one of the limitations of ECN, namely, the small number and non-random distribution of sites, a feature which limits the extrapolation of results. However, ECN does not function in isolation – it is linked to the various sectoral observing systems and, in particular, to the national networks involved in the routine monitoring of water quality and quantity by the UK's Environmental Protection Agencies. It is also linked to the Countryside Survey (Barr *et al.* 1993) which includes

freshwater observations and represents a larger, more extensive, stratified sampling system with observations made at 5–10 year intervals. A Land Cover Map (Fuller, Groom & Jones 1994) provides complete cover of Great Britain, obtained from satellite imagery, with the option of frequent observation, but has limited value for detecting freshwater changes. As with ECN's terrestrial sites, the various intensive catchment studies of NERC and other institutes and universities provide the detailed understanding of the dynamics and controls of processes necessary to interpret observations made within the freshwater component of ECN. The combination of these four levels of resolution provides GB with a strategic monitoring design which is possibly the most complete system in the world.

At a time when major efforts are being made by international organisations to develop systems to detect changes over larger areas, the increasing strength of the European Environment Agency (EEA) provides one of several wider contexts for information generated by ECN. It may be significant that the first EEA Environmental Monograph was an assessment of the state of European rivers and lakes (Kristensen & Hansen 1994). Such assessments, as well as those by UK government, depend on the quality and availability of data from systems like ECN. The same applies to the emerging Global Observing Systems, the hierarchical strategy of which involves the collection of reliable, representative, long-term data from the world's land and freshwater ecosystems and which will provide long-term information on the state of the environment.

Finally, it is a pleasure to acknowledge the contribution of so many people and organisations to the establishment and operation of ECN, and in particular to the publication of this handbook of protocols. Special thanks go to: Ivan Heaney (Chairman); to members of the ECN Freshwater Working Group and its successor the Statistical and Technical Advisory Group, for their persistence in a long and difficult exercise; to Mike Sykes, Terry Parr and members of the ECN Central Co-ordination Unit for their contribution to the collation of data, quality control and to the writing and editing of the protocols; to the unsung site researchers whose testing and experience in implementing the protocols have been crucial; and to the Departments and Agencies without whose visionary commitment ECN would not have been possible.

Professor O.W. Heal
Formerly Chairman, ECN Steering Committee

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Chapter 1 INTRODUCTION

Monitoring environmental changes

The occurrence of far-reaching changes in the earth's environment is now well-recognised by scientists, politicians and public, and this recognition has generated a growing national and international interest in detecting and monitoring environmental changes. At the global scale these changes are caused by largely man-induced changes in climate, atmospheric composition and land use (International Geosphere-Biosphere Programme 1992), factors which also operate at regional and national scales where they are often exacerbated, or occasionally mitigated, by local factors.

International efforts to obtain reliable information on the responses of natural and managed ecosystems to global environmental changes have burgeoned during the last decade and have resulted in the involvement of many organisations and their associated actual or planned networks.

There is a growing movement towards harmonised monitoring which, whilst it may be carried out by different organisations, produces reliable data, capable of comparison and integration at both national and international levels. The national environmental data resource is concentrated in databases and Geographic Information Systems (GIS) at designated Environmental Data Centres. Contributions are made from UK environmental monitoring programmes to international programmes such as the UN-ECE's International Co-operative Programme on Integrated Monitoring of Air Pollution Effects on Ecosytems (IMP), and the United Nations Environment Programme's Global Environmental Monitoring System (GEMS) and Global Resources Information Database (GRID).

Environmental monitoring in the UK

The UK has a long history of environmental monitoring, sampling being carried out by a multiplicity of organisations for a wide variety of purposes. The majority of this monitoring is designed to ensure that there is compliance with policies of environmental regulation set out in international, national and local agreements. In addition, monitoring provides information on the effectiveness of policies already being implemented and may lead to proposals for new or modified policies or actions, especially where early warnings of environmental changes have been recognised. Finally monitoring is concerned with the measurement of background levels and the provision of benchmark data for research and policy purposes, as well as with re-assuring the public.

Most UK environmental monitoring is de-centralised, the majority of sampling being carried out by local government, other public sector bodies including inspectorates, individual factories and at both central Government and other research laboratories. Most monitoring is also sectoral, in the sense that particular monitoring systems have been devised and developed to relate to a particular sector of the environment. Various central UK Government departments have responsibilities in the areas of, for example, air quality, water, land, soil, natural resources, flora and fauna. There is co-ordination of monitoring programmes within sectors, (eg air quality monitoring networks), and also across sectors where this approach is necessary, (eg monitoring radioactivity in air, drinking water, the sea, and in agricultural products).

Non-governmental organisations play an important role in environmental monitoring; they often optimise the involvement of the large pool of available amateur expertise and inform the public of environmental changes which are taking place.

Monitoring freshwaters in the UK

Freshwater ecologists in the UK have long recognised the value of multi-disciplinary, long-term research and monitoring. The first comprehensive study of change in the lakes in the English Lake District was conducted by W.H. Pearsall between 1913 and 1928 (Pearsall 1930, 1932). A few years later, the Freshwater Biological Association (FBA) was established on the shores of Windermere and it implemented a comprehensive lake survey programme using methods which have changed very little over the years (Lund & Talling 1957; Macan 1984). Elsewhere in the UK, several university research groups developed an interest in freshwater ecology and started a number of shorter-term surveys on rivers and reservoirs as well as on natural lakes. In the 1950s, one of the most productive groups was that led by W. D. Slack at Loch Lomond (Slack 1957). Several other university groups were set up in the 1960's, the most influential being those based at the University of Liverpool (see Hynes & Yadav 1985) and the London University colleges (see Duncan 1990). Much of the work done in London was centred on the Thames reservoirs where the Metropolitan Water Board was responsible for developing new methods and models (Ridley 1970; Steele 1972). Another significant influence in the 1970s was the research group established by the International Biological Programme on Loch Leven, Kinross (Morgan 1974). Most of the university research groups established during this period have now been dispersed but the work at Loch Leven continued and the site is now part of the ECN.

All effluent discharges into groundwater, inland and coastal waters in the UK require the consent of a regulatory authority. In England

and Wales the Environment Agency (EA) is the responsible agency and it maintains public registers containing information about water quality, discharge consents, authorisations and monitoring. Similar arrangements apply in Scotland and in Northern Ireland, where control is exercised respectively by the Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service. All standing waters used for public water supply are monitored at regular intervals by the Water Companies and a large number of river sites are now monitored systematically by the statutory authorities. The most comprehensive freshwater monitoring programme in the UK is the Harmonised Monitoring Scheme (Simpson 1980). This operational scheme was established in 1974 to co-ordinate the collection of river water quality data throughout Britain and has recently evolved to include a separate sampling programme for Scotland.

The Environmental Change Network

The need for a general-purpose network designed for long-term, integrated environmental monitoring in the UK, especially in relation to current or future major anthropogenically induced factors, has been emphasised on numerous occasions and has eventually led to the formation of ECN (Tinker 1994). As early as 1976 a NERC Working Party on Biological Surveillance (NERC 1976) had noted the need for detailed surveillance at a limited number of sites with the objective of observing natural changes on a year-to-year and long-term basis. It was suggested that protected areas and sites with intensive research programmes or where substantial information was already available should be used for this purpose. Almost a decade later a House of Lords Select Committee on Science and Technology recommended that the effects of agricultural practices should be monitored by 'a small and highly selective network of projects... to give early warning of environmental consequences' (HMSO 1984).

As a consequence of these recommendations and a wide recognition in the scientific community of the need for a network which would meet the requirements of environmental change research and monitoring, NERC undertook, in 1986, to consult government departments and research organisations primarily concerned with agriculture and the environment to explore the setting up of such a network. A Working Group on long-term reference sites was set up which produced a series of recommendations for the establishment of a national network of sites which would meet the requirements of different interested organisations (NERC 1986). These recommendations were taken up and put into effect by a consortium of agencies which agreed to contribute to the operation of the network, which became the UK Environmental Change Network.

The rationale for proposing a network of sites is summarised by Heal (1991), as follows:

1. Study sites are an essential component of ecological research. To answer questions on changes in the environment, we need sites which represent the main environmental, ecological and management variations in the UK. While studies of some individual topics will require other sites with particular characteristics, a 'core' network will provide the opportunity to use existing information on the related topics.

2. Long-term studies are required to monitor changes external to the system which take place gradually or at infrequent intervals. Responses to those changes may occur through species or processes which have a slow turnover time, or through a series of linked short-term events, the results of which are only apparent in a long-term study.

3. In addition to delayed and serial responses, it is also necessary to distinguish between the different factors which cause, or interact to cause, change. For these reasons it is important to have sites with integrated or multi-media monitoring and to carry out both observational and experimental research.

4. The scientific case for a network of long-term study sites in the UK is strong. Information on environmental changes and on their consequences is a serious need in government. By concentrating on established sites, the cost of creating such a network can be kept to a minimum.

ECN objectives

The objectives of ECN are as follows:

To obtain uniform and comparable long-term data sets at selected sites by means of measurement at regular intervals of variables identified as being of major environmental importance.

To provide for the integration and analysis of these data sets so as to identify environmental changes and to improve understanding of the causes of such changes.

To make these long-term data sets available as a basis for research and for the prediction of possible future changes.

To provide, for research purposes, a range of representative sites where there is good instrumentation and reliable environmental information.

ECN design

The ECN aims to monitor changes in selected biota in addition to the physical and chemical environment. The programme thus falls within the definition of 'ecological monitoring' (Hinds 1984). It is not surprising, therefore, that the design of the ECN has encountered the problems which the author identifies as needing to be overcome in successful ecological monitoring designs and which can be summarised as:

> selecting and quantifying specific entities within the continuous spatial and temporal flux;
> specifying appropriate replication standards in a world that is full of unique places;
> expense.

The need for long-term observations in ecology has been set out by Likens (1983) and Strayer *et al.* (1986) and summarised by Woiwod (1991), who also discusses the scientific, political and personal problems associated with long-term experiments and observations. The problems of sustaining a long-term programme such as ECN are exacerbated to some extent by the participation of many organisations, all of which have different objectives, are publicly funded, and which are unable to commit funds for more than 3–5 years in advance. Nevertheless it was believed that the programme could be sustained if it was not too ambitious, had a well-defined concept and organisation, was able to operate successfully within agreed target budgets, and if the network as a whole provided added value to the individual contributions of sponsoring agencies. The initial steps to be taken were as follows:

1. Select a series of variables related to climate, pollution and land use, changes in which would drive the states of a second set of 'response' variables. Both driving and response variables should be interpretable, informative, comparable and repeatable between sites and times, and response variables should be sensitive to changes in the driving variables. Within these constraints they should also, where possible, be simple and cheap and avoid labour-intensive operations. The variables should be selected so as to be measurable at each of a series of sites which may have a wide range of conditions.

2. Establish agreed, strict and clear protocols for the sampling and recording system to be used for measuring each variable, for chemical analysis where necessary, and for quality control and assurance of the data.

3. Establish methods for managing and storing the data.

Development of the network

Although ECN was conceived of as a programme covering a wide range of natural, semi-natural and managed terrestrial ecosystems as well as freshwaters, the need for urgent implementation of the programme led to the adoption of a step-by-step approach to network establishment. It was decided that attention would first be focused on setting up a network of terrestrial sites, to be followed as soon as possible by a parallel and linked network of freshwater sites, which would include rivers and lakes. Each contributing agency agreed to provide one or more sites and the resources to carry out an agreed suite of ECN measurements, or to provide equivalent resources to support the general operation of the network. A list of current contributors is provided in Table 1 (page 40); it includes agencies responsible for both the freshwater and terrestrial sites. Additional information on the contributing agencies is provided in Chapter 5 (page 131).

Site selection

Criteria for selection of ECN Freshwater sites are:

- a wide geographical spread, with a range of both upland and lowland catchments;
  known anthropogenic influences with site catchments having a known history of past change;
- preferably already monitored for a wide range of determinands;
- adequate size, in terms of flow or residence time, to have the capacity to respond to and integrate changes in their catchments.

It was recognised from the outset that it would be difficult to obtain absolute guarantees of long-term financial security and, as with the terrestrial sites, participating agencies could only be asked to state their firm intention of continuing support for a target number of years. Physical security, from the point of view of continuity of catchment land use practices, would also be difficult to achieve; it was inevitable that periodic disruptions such as afforestation and clear-felling would continue where forestry was the main land use. The main drivers of change in freshwaters were expected to be the same as those at terrestrial sites, (ie climate, pollutants and land use), and the question of whether the network should be concerned with only clean or only polluted waters was considered. It was concluded that there should be a spread of qualities which might allow the effects of the removal or addition of impacts to be studied. Pragmatism, and the need to meet the criteria outlined above, demanded that for the most part sites where monitoring was already in place should be used in the network and the selection was made accordingly from sites offered by sponsoring organisations.

There are currently 42 freshwater sites in ECN (Figure 1, page 17), two of which are joint terrestrial and freshwater sites. The distribution of the freshwater sites is currently being examined in relation to the main patterns of environmental variation across the UK and is expected to show that they are reasonably representative of the main landscape types. The sites have not been analysed in relation to climate, and at present there is no standardised method for meteorological recording at ECN freshwater sites, although it is anticipated that such routine recording will eventually be incorporated in the programme.

Variable selection

Variables were selected because they may indicate the possible causes and consequences of environmental change in the aquatic environment. The causes of such change embrace changing climate, land use and industrial, urban and agricultural pollution.

Aquatic systems can be considered to consist of 'master variables' which are common to all freshwaters and include temperature, pH, major ions, oxygen concentration and transparency. Changes in these may significantly affect the system as a whole. Other variables mainly measure chemical concentrations, which are susceptible to changing inputs and biogeochemical processes, and biological components reflecting the overall water quality.

Justification for selection of variables

1. Master Variables

Temperature	Fundamental physical property of water. Influences biogeochemical processes. Major variable in climate change studies.
pH	Measures hydrogen ion concentration of waters. Short-term shifts from air equilibrium values can be caused by depletion of carbon dioxide by plant growth and imbalances in the respiration rate of living organisations; long-term reductions in pH are related principally to increasing acidification.
Oxygen	Released into water by photosynthetic processes and consumed by respiration and chemical oxidation. Essential element in controlling biogeochemical processes.
Turbidity/ Secchi disc	The only optical measurements. Measures of water transparency and underwater penetration of light. Important for determining plant growth.

Suspended solids	Gravimetric measurement of organic and inorganic particles in suspension.
Flow	Necessary for the calculation of loadings. Measure of catchment runoff and can be used to indicate changes in climate and both urban and rural land use. Contributions of significant discharges (floods) can be detected as can the effects of river management schemes. Efficacy of flow measurements can be affected by excessive macrophyte growth, exceptional low flows, and changes in channel cross-section due to deposition or flood events.

2. Major ions

Alkalinity, Chloride Sulphate, Sodium Potassium, Calcium Magnesium	Major ions give a measure of the basic chemical composition of the water. This may be altered by changes in terrestrial and/or atmospheric inputs.

3. Major plant nutrients and associated variables

Ammonium Nitrate Nitrite Total nitrogen Soluble reactive phosphorus Total phosphorus Particulate phosphorus Silicate Total organic carbon Particulate organic carbon Biological oxygen demand Suspended solids (105°C followed by ashing at high temperature to give measure of particulate carbon)	These variables give measures of the nutrient status of waters and information on their productivity. They are susceptible to change resulting from changes in terrestrial (rural, urban and industrial) and atmospheric inputs. Their total and particulate fractions can give valuable indicators of changing inputs and productivity. This is particularly useful when ratios of particulate C:N:P can be determined.

4. Transition elements

Iron Manganese	These elements are important in biogeochemical processes in lakes, especially those which stratify. Seasonal increases during late summer and autumn are often associated with oxygen depletion in deep water.

5. Other elements

Aluminium — This element and its chemical state is pH dependent. It is of interest in lakes sensitive to, or undergoing, acidification. It may also give an indication of erosion in some circumstances. This element and its chemical state are pH dependent. It is of interest in lakes sensitive to, or undergoing, acidification. In some circumstances it may also give an indication of erosion.

6. Heavy metals

Mercury, Cadmium, Copper, Zinc, Tin, Vanadium, Nickel, Arsenic, Lead — The presence of metals will be indicative of industrial discharges (aerial and effluent), sewage discharges, waste disposal, mining, and surface runoff from both urban and rural areas. In urban areas the contribution of metals from road surfaces is considerable and is associated mainly with the carried sediment. Metals are also associated with livestock slurries because copper, zinc and arsenic are incorporated in feed concentrates. The contribution from sewage sludge applied to land is likely to increase as a consequence of the 1998 ban on disposal at sea. Important factors controlling the sediment – water metal partitioning include changes in the ratio of flow to suspended solids, dissolved organic content, ionic strength, pH, redox conditions as well as biochemically mediated reactions mobilising metals. Apart from sediments, metals will be accumulated by plankton, macrophytes and invertebrates.

7. Biological variables

Chlorophyll *a*, Periphyton, Macrophytes — Measures of plant biomass and indicators of nutrient status. Will affect levels of oxygen concentration and pH. Excessive growths will limit light penetration and contribute to organic loadings of sediment.

Invertebrates — Species and diversity of macro-invertebrates are useful indicators of general water chemistry, and for rivers a baseline against which data may be evaluated is provided by RIVPACs. Lake classification systems have also been based, successfully, on invertebrates, (eg Chironomidae). These are sensitive, for example, to trophic status and acidification. While littoral fauna are much more variable than profundal benthos, they are likely to be more responsive to change in water

quality in the short-term and are easier and cheaper to sample. Routine sampling of invertebrates will therefore be confined to littoral communities but core samples from profundal regions may also be used to determine, retrospectively, longer-term changes in the profundal fauna.

Zooplankton — Measure of planktonic secondary production. Forms an important link in the food chain between the phytoplankton and fish. Some species are sensitive to relatively subtle changes in water chemistry.

Network sites

Figure 1 (page 17) shows the locations of the 42 freshwater sites as well as the 12 terrestrial sites. The freshwater sites are described below. In these descriptions latitude, longitude, National Grid Reference (NGR) and Irish Grid Reference (IGR) refer to the location at which chemical samples are taken (see Protocol FWC, page 56).

L01 Upton Broad

Norfolk, England (Lat 52° 40'N; Long 1° 32'E; NGR 6387 3134)
Sponsor: Environment Agency, Anglian Region

Upton Broad is a shallow lowland lake, formed by the flooding of peat diggings, which were abandoned in the 14th century. It has an area of 6.9 ha and an approximate mean depth of 0.8 m. The broad lies in the valley of the River Bure at an elevation of less than 10 m above Ordnance Datum (AOD), but is isolated from the river system and is groundwater fed, with some drainage from surrounding land. Geologically, the area is underlain by Quaternary deposits of Norwich Crag, with glacial till and outwash deposits at the surface. The broad forms part of the Upton Broad and Marshes Site of Special Scientific Interest (SSSI). It is considered to have been relatively unaffected by the eutrophication that has damaged most of the lakes in the region, and supports a population of the nationally rare aquatic macrophyte *Najas marina*. The broad is surrounded by a band of alder (*Alnus glutinosa*) carr (wet woodland). To the north of the broad are drained grazing marshes which form part of the Broads Environmentally Sensitive Area, and to the south the catchment is given over to more intensive arable agriculture. The broad is used for angling by a private club; there is no other public access.

L02 Hickling Broad

Norfolk, England (Lat 52° 44'N; Long 1° 35'E; NGR 6415 3215)
Sponsor: Environment Agency, Anglian Region

Hickling Broad is the largest of the lakes that make up the Norfolk Broads, and is a result of extensive peat digging in the 12th and 14th

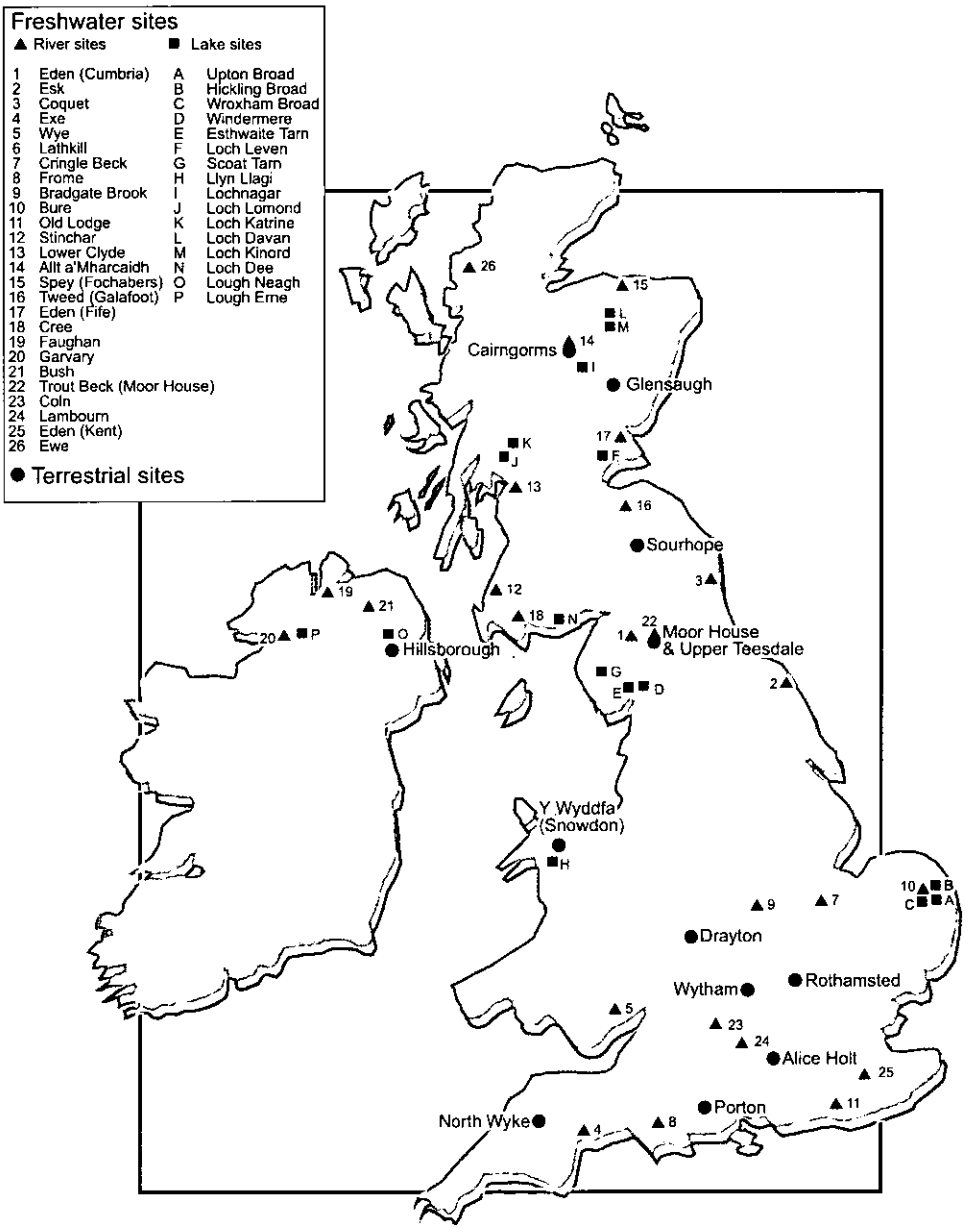

Figure 1. Location of ECN freshwater and terrestrial sites

centuries followed by flooding due to a rise in sea-level. The broad has an area of 141.1 ha, and an approximate mean depth of 1.3 m. It lies close to sea level in the valley of the River Thune and is connected to the river by an artificial channel approximately 0.7 km long. The broad is subject to a small tidal variation in water height and is brackish. It is part of a National Nature Reserve (NNR), owned and managed by the Norfolk Wildlife Trust. The broad is surrounded by extensive areas of reed bed and grazing marsh, although parts of the catchment have been deep-drained for arable cultivation.
Geologically, the area is underlain by Quaternary deposits of Norwich Crag, with glacial till and outwash deposits at the surface. The broad is used extensively for recreational activities – sailing, windsurfing, tourist cruisers and angling. The broad is not subject to any point sources of nutrient input and has maintained a substantial aquatic macrophyte population in recent years, although there have been signs of eutrophication. At times it has suffered extensive fish kills due to the presence of the alga, *Prymnesium parvum*.

L03 Wroxham Broad

Norfolk, England (Lat 52° 41'N; Long 1° 25'E; NGR 6312 3167)
Sponsor: Environment Agency, Anglian Region

Wroxham Broad is a shallow, lowland lake formed from the flooding of mediaeval peat diggings which were abandoned in the 14th century. The broad has an area of 34.4 ha and an average depth of 1.3 m. It is located in the middle reach of the River Bure, close to the upper tidal limit, at an elevation of less than 10 m AOD. The broad lies on the west side of the river, to which it has two navigable openings. It is separated from the river channel by a narrow, tree-covered bank. The broad has been subject to serious eutrophication, largely as a result of the discharge of treated sewage effluent to the River Bure. Since 1986 a programme of phosphorus removal has been in operation at the major sewage treatment works affecting the river, and this stretch of river is now designated a Sensitive Area under the Urban Waste Water Treatment Directive. The low gradients of the area and seasonally low flows of recent years have meant that the flushing rate of the broad is slow, although exact retention times are unknown. The surrounding catchment is underlain by Quaternary deposits of Norwich Crag, with chalk at depth, and superficial glacial till and outwash deposits. The area is subject to intensive agricultural activity, although surrounding the broad itself there are small areas of alder carr (wet woodland). The broad is used extensively for recreational purposes, particularly in the summer months.

L04 Windermere

Cumbria, England (54° 24'N; Lat 2° 57'W; NGR 3382 5007)
Sponsor: Natural Environment Research Council

Windermere lies in the north-west corner of England in the English Lake District, an area of great natural beauty which has been a tourist destination since the romantic revival of the 18th century.

The dominant geological structure of the Lake District is that of a dome of Paleozoic rocks formed by uplift in the Tertiary. This uplift produced a radial drainage pattern which was enhanced during the Pleistocene glaciation, with the major lakes occupying bedrock basins in steep-sided, flat-floored valleys. Windermere is the largest natural lake in England having a surface area of 14.8 km^2 at an altitude of only 40 m AOD. The lake itself is divided by a shallow sill into two basins; the North Basin has a surface area of 8 km^2 and maximum depth of 64 m and the South Basin has a surface area of 6.7 km^2 and maximum depth of 42 m.

The North Basin of Windermere, which is the ECN sampling site, has a catchment of 180 km^2 which drains into the lake *via* two main rivers, several small tarns (lakes) and several streams. The catchment is mainly hill land, grazed by sheep throughout the year but also used intensively for recreational purposes. The villages in the valleys are also major tourist destinations with consequent increases in the sewage input to the lake. Over the past 50 years levels of dissolved reactive phosphorus in the lake have more than doubled, reaching their highest levels in the 1980s. The effluent discharged into the North Basin of Windermere from the main sewage works is now phosphate-stripped in an effort to reduce the nutrient loading to the lake.

The lake itself designated as SSSI; it is a source of potable water, a major recreational facility and a specialised fishery for charr (*Salvelinus alpinus*). The FBA, and latterly the Institute of Freshwater Ecology (IFE), have maintained a laboratory on the shore of Windermere for over 50 years and in consequence there is a large body of scientific literature based on Windermere and other Lake District lakes.

L05 Esthwaite Water

Cumbria, England (Lat 54° 22'N; Long 2° 59'W; NGR 3360 4972)

Sponsor: Natural Environment Research Council

Esthwaite Water is a natural lake situated in a glacial valley and is generally agreed to be the most productive or eutrophic lake in the English Lake District. It lies approximately 65 m AOD and has an area of 1 km^2 and a maximum depth of 15.5 m. The average retention time is 90 days. The catchment area is 17.1 km^2 and the hills are composed geologically of Bannisdale slates and grits. The surrounding land is used chiefly for agricultural purposes and forestry. The lake is a Grade 1 SSSI and has been a designated 'Ramsar' site since November 1991.

The diverse aquatic invertebrate fauna includes a number of species with restricted distributions in Britain, one of which is the flatworm, (*Bdellocephala punctata*). The slender naiad (*Najas flexilis*), which is listed as Nationally Scarce, has been found in Esthwaite Water.

Esthwaite waterweed (*Hydrilla verticillata*) was discovered at Esthwaite Water in 1914 by W H Pearsall; this species is known only from this location in Britain and was last seen in 1941.

Artificial enrichment of the lake occurs by input from the Hawkshead Sewage Treatment Works (which has operated a continuous programme of phosphate-stripping since 1989) and by effluents from the fish farm which is situated towards the south of the lake.

The lake undergoes summer stratification with oxygen depletion regularly below 7 m and sometimes as shallow as 5 m. The phytoplankton tends to be dominated by diatoms in spring and by cyanobacteria for much of the summer.

L06 Loch Leven

Tayside, Scotland (Lat 56° 12'N; Long 3° 23'W; NGR 3135 7011)

Sponsor: Natural Environment Research Council

The loch covers 13.3 km^2 and lies at 106 m AOD. The catchment has a maximum altitude of 497 m AOD and its area of 145 km^2 comprises mainly arable crops (38.6%) and improved pasture (31.5%), but also upland moor (11.6%), coniferous woodland (3.8%), heathland (3.5%), rough grazing (3.5%), suburban/rural development (2.2%) with the rest (5.3%) being deciduous woodland, bog, bare ground and inland water. Poultry rearing units of relatively small area are also significant. High phytoplankton biomass is a major feature; this is due firstly to the following photosynthesis-promoting features (i) a moderate depth - mean 3.9 m, (ii) a clear water (little peat-staining) with >5m Secchi readings at low chlorophyll levels, and (iii) a rich supply of nutrients. Secondly, flushing rates are moderate, rarely >0.2 lake volumes per month. However, a major determinant of the amounts of phytoplankton per unit of total phosphorus loading depends very much on *Daphnia* population densities. Depending on the highly capricious, 'oceanic' weather regime in this part of the world, the loch stratifies intermittently and then mainly in the two deep kettle-holes which extend down to a depth of approximately 25 m.

The dense algal blooms threaten the world-famous trout fishery, although probably not the fish populations *per se*; they have almost certainly contributed to declines in macrophyte abundance and species richness and thus to the diversity of invertebrates associated with the wide spectra of physical and chemical conditions provided by such macrophytes. Special concern has been expressed over macrophyte losses in relation to the wildfowl populations, on the basis of which the loch is designated a 'Ramsar' site and NNR. Deterioration in water quality has also had a negative effect on local tourist and paper-making industries.

L07 Scoat Tarn
Cumbria, England (Lat 54° 29'N; Long 3° 18'W; NGR 3158 5104)
Sponsor: Department of the Environment, Transport and the Regions (through the Acid Waters Monitoring Network)

Scoat Tarn, in the English Lake District, is a typical mountain corrie lake, being small and deep with an area of 5.2 ha and a maximum depth of 20 m. The lake lies in a west-facing valley at an altitude of 602 m AOD and drains into Wastwater *via* the Nether Beck. The catchment comprises a small corrie (95 ha) with steeply sloping walls and three summits in excess of 825 m. The bedrock is Ordovician tuff (undifferentiated) of the Borrowdale Volcanic series and the local soils are mainly shallow, peaty rankers. The eastern slopes are mainly of rock and boulders while those to the north are less steep and are covered in rough grass and *Sphagnum* moss. Land use is confined to low-intensity sheep grazing.

Scoat Tarn is an Acid Waters Monitoring Network (AWMN) site, classified as having high acid deposition.

L08 Llyn Llagi
Snowdonia, Wales (Lat 53° 01'N; Long 4° 01'W; NGR 2648 3483)
Sponsor: Department of the Environment, Transport and the Regions (through the Acid Waters Monitoring Network)

Llyn Llagi occupies a north-facing corrie in the central area of the Snowdonia region of North Wales. The lake lies at 380 m AOD beneath a steep backwall and comprises a deep, almost circular basin (maximum depth 16.5 m) bordered by an extensive, shallow (1 m deep) rim. The lake covers an area of 5.7 ha and the primary inflow constitutes the outflow stream from Llyn yr Adar. The lake drains towards the north-west to the Nanmor valley. The catchment (157 ha) consists primarily of Ordovician slates and shales of the Glanarfon series. The backwall is composed of a large doleritic intrusion with small intrusions of fine microgranites and volcanic tuff. The catchment soils are mainly stagnopodsols and gleys, interspersed with blanket peats. The vegetation is characterised by heather (*Calluna vulgaris*), purple moor-grass (*Molinia caerulea*) and cotton grass (*Eriophorum* spp), and the catchment is grazed at a low intensity by sheep. The lake and much of the catchment lie within a designated SSSI.

Llyn Llagi is an AWMN site, classified as having high acid deposition.

L09 Lochnagar
Grampian, Scotland (Lat 56° 58'N; Long 3° 14'W; NGR 3253 7862)
Sponsor: Department of the Environment, Transport and the Regions (through the Acid Waters Monitoring Network)

Lochnagar lies at an altitude of 785 m AOD in the centre of the granite massif which comprises much of Balmoral Forest. Lochnagar is

a corrie loch and lies below a north-east facing, steep backwall which rises to the summit of the same name. The loch is 9.8 ha in area with its deepest point at 24 m, and drains north-east into a tributary of the River Dee. Snow-melt comprises a major input to the loch which freezes regularly each winter. The precipitous catchment (91.9 ha) is composed of biotite granite, overlain in places by blanket peat, but dominated by bare rock with extensive fields of large boulders and coarse screes. The sparse moorland vegetation of the catchment is dominated by a community of stunted heather and bilberry (*Vaccinium myrtillus*). The catchment is above the limit for summer sheep grazing in the region, and there is no evidence for any landuse change or active land management.

Lochnagar is an AWMN site, classified as having moderate acid deposition.

L10 Loch Lomond

Strathclyde Region, Scotland (Cailness: Lat 56° 13'N; Long 4° 41'W; NGR 2335 7062)
Sponsor: Scottish Environment Protection Agency, West Region

The Loch Lomond basin is of glacial origin, formed by an ice sheet moving southward from the Ben Lui area and depositing eroded material in the southern-most part around Balloch, thus ensuring that the loch was freshwater rather than marine. It is the largest (by surface area) body of freshwater in Britain, with a surface area of 71 km^2. The natural catchment area is ten times greater, at 781 km^2.

The two main feeder rivers are the River Falloch at the northern-most point, with a mean flow of 6.8 cumecs, and the River Endrick entering on the south-eastern side of the loch, with a mean flow of 7.8 cumecs. They have markedly different catchments – that of the Falloch is mountainous with a catchment area of 80 km^2, whilst the Endrick has a typical lowland rural catchment of 220 km^2. There are distinct differences in the chemistry of the two rivers, reflecting the differences in the geology of their catchments. The Highland Boundary Fault cuts across the lower part of Loch Lomond, but there is also a narrow physical restriction halfway down the length of the loch. For these reasons, the water chemistry and topography of the so-called Northern and Southern Basins are quite different and, as a result, there are two ECN sampling sites, one in each basin.

L12 Loch Katrine

Central Region, Scotland (Lat 56° 14'N; Long 4° 26'W; NGR 2486 7082)
Sponsor: Scottish Environment Protection Agency, East Region

Loch Katrine lies within the catchment of the River Teith, a major tributary of the River Forth. The loch forms part of the water supply system to the city of Glasgow and the loch and the whole of its catchment is owned by the West of Scotland Water Authority which

controls all activities within the area. Water from two neighbouring lochs, Loch Arklet and Finglas Reservoir, is piped to Loch Katrine and water for Glasgow is moved 24 miles through underground aqueducts to Milngavie Reservoir on the outskirts of the city. Loch Katrine lies at an altitude of 116 m AOD (at top water level) and at its deepest point is over 140 m deep. It has a capacity to store 64.6 million litres of extremely high quality water. The loch is bounded at its southern end by a low dam and the surrounding hills rise to over 700 m on the northern and southern shores. The bed of the loch shelves away very steeply and only at its western end are there large areas of shallower water away from the shoreline. Vegetation in the catchment is grazed by sheep and red deer (*Cervus elaphus*) and consists mainly of rough heather and grassland with forested areas to the east. Being part of the Trossachs it is a very popular tourist area during the summer months.

L13 Loch Davan

Grampian Region, Scotland (Lat 57° 06'N; Long 2° 55'W; NGR 3441 8008)

Sponsor: Scottish Environment Protection Agency, North Region

Lochs Davan and Kinord are situated adjacent to each other in an area of the River Dee catchment known as the Muir of Dinnet. The Muir of Dinnet (area 2 287 ha) is an SSSI and a NNR designated because of its value as a habitat for flora and fauna, and important geomorphological features. The Muir forms the south-western corner of the Howe of Cromar, a wide saucer-shaped plain at the foot of the Grampian Mountains. The landscape of the area was moulded by gravel and meltwater in the post-glacial era, and Lochs Kinord and Davan are kettleholes (ice depressions), surrounded by fluvio-glacial hummocks, ridges and hollows. Loch Kinord (area 79.0 ha) is oligotrophic whereas Loch Davan (31.1 ha) is mesotrophic with recent research suggesting a transition towards eutrophication. The difference in trophic status reflects the higher proportion of agricultural land use in the Davan catchment.

L14 Loch Kinord

Grampian Region, Scotland (Lat 57° 05'N; Long 2° 55'W; NGR 3440 7995)

Sponsor: Scottish Environment Protection Agency, North Region

Lochs Kinord and Davan are situated adjacent to each other in an area of the River Dee catchment known as the Muir of Dinnet (see description of Loch Davan above). Loch Kinord (area 79.0 ha) is oligotrophic whereas Loch Davan (31.1 ha) is mesotrophic and the difference in trophic status reflects the higher proportion of agricultural land use in the Davan catchment.

Loch Kinord possesses a rich aquatic flora, and a full range of hydroseral plant communities ranging from emergent fens dominated by sedges, to bog myrtle (*Myrica gale*) scrub, fen carr and birch woodland. It also has a rich invertebrate fauna and is an important site for aquatic beetles. About 80 species of birds breed within the

SSSI and the lochs are important refuges for passage and wintering wildfowl, particularly greylag geese (*Anser anser*) and wigeon (*Anas penelope*). Since the early 1980s, introduced ospreys (*Pandion haliaëtus*) have colonised the area, and both lochs are important rearing and feeding grounds for young otters (*Lutra lutra*).

Pollen preserved in the sediments of Loch Kinord record an almost complete sequence of Devensian late-glacial and Flandrian vegetation history so that these two lochs are important reference sites for reconstructing changing environmental conditions in north-east Scotland since the last ice-sheet melted.

L15 Loch Dee

Dumfries & Galloway Region, Scotland (Lat 55° 05'N; Long 4° 23'W; NGR 2478 5797)
Sponsor: Scottish Environment Protection Agency, West Region

Loch Dee forms the headwaters of the River Dee and has a surface area of 1 km^2, with a total catchment area of 15.6 km^2. It has three principal sub-catchments, the Dargall Lane, the White Laggan and the Black Laggan Burns (30% planted with Sitka spruce (*Picea sitchensis*)), and the Green Burn (67% planted with Sitka spruce). It has highly variable annual rainfall a predominant feature being dry periods in spring and summer. Average rainfall is moderately acidic (pH 4.6 – 4.9) and its chemistry is dominated by salts of marine origin, mainly sodium (Na^+), chloride (Cl^-) and sulphate (SO_4^{2-}–S); for most samples the concentration ratios between the ions match those of sea water. The topography and land use affect the flows in the sub-catchments, giving a wide dynamic range of flows in the main tributaries. The Dargall Lane is steep and peaty, whereas the other two sub-catchments are afforested. As with many of the catchments in the Galloway area the geology comprises igneous rocks such as granite, with thin overlying soils giving poor neutralising and buffering capacities.

L16 Lough Neagh

County Down, Northern Ireland (54° 37'N; Long 6° 24'W; IGR 3030 3750)
Sponsor: Department of Agriculture for Northern Ireland

Lough Neagh covers 386 km^2 and is by far the largest area of freshwater in the British Isles. Situated in north-east Ireland, it has a drainage basin of 4450 km^2, which is shared between Northern Ireland (91%) and the Republic of Ireland (9%). The average water retention time is 15 months. Although large in area, the lake is relatively shallow with a mean depth of 8.9 m (max. 25 m). This, combined with its great size and a mild and windy oceanic climate, ensures that the water column is generally well mixed. The lake supports commercial fisheries for eels (*Anguilla anguilla*), pollan (*Coregonus autumnalis pollan*), perch (*Perca fluviatalis*) and trout (*Salmo trutta*) of which the eel fishery is the most significant, with an annual catch in the region of 600 t. Lough Neagh is hypertrophic with a mean annual total phosphorus concentration of 160 $\mu g\ P\ l^{-1}$.

Attempts to lower phosphorous concentrations in the lough by curtailing point sources of phosphorous have been unsuccessful due to increasing inputs from diffuse sources. Levels of phosphorous in the lough support large phytoplankton populations with annual chlorophyll *a* concentrations typically in excess of 60 $\mu g\ l^{-1}$. The dominant alga is the cyanophyte *Planktothrix agardhii* and the phytoplankton is now less diverse than in the late 1960s when regular monitoring began. Since then there has been regular monitoring of the plankton, lake and river nutrient concentrations, which have been used to produce nutrient budgets for the lake.

L17 Lough Erne

County Fermanagh, Northern Ireland (Lat 54° 29'N; Long 7° 51'W; IGR 2101 3595)
Sponsor: Department of Agriculture for Northern Ireland

Lough Erne is the collective name given to Upper Lough Erne (34.5 km^2) and Lower Lough Erne (109.5 km^2), which are connected by the River Erne in County Fermanagh, Northern Ireland. The Upper Lough and the shallower regions of Lower Lough Erne present an example of a flooded drumlin landscape which has created an intricate mosaic of land and water. As a consequence of differences in depth and area, the water retention time of the Upper Lough is less than one month while that of the Lower Lough is four months. Passing from the shallow Upper Lough (mean depth 2.3 m) and through Lower Lough Erne (mean depth 11.9 m), phytoplankton abundance is reduced and algal composition alters, as do nutrient and temperature cycles. Phosphorus concentrations (100 $\mu g\ P\ l^{-1}$) in the Upper Lough create eutrophic conditions, with high summer chlorophyll *a* concentrations, but phytoplankton abundance in the deep open water of the Lower Lough is more typical of a mesotrophic water body despite comparatively high phosphorus concentrations (60 $\mu g\ P\ l^{-1}$). The paucity of phytoplankton in this region is attributed to a high background light attenuation from the peat-stained water and the greater depth of the mixed water zone (>35 m). The lake supports a fish population dominated by a recent introduction, the roach (*Rutilus rutilus*), as well as pike (*Esox lucius*), perch, bream (*Abramis brama*), trout and the pollan. The Zebra mussel (*Dreissena polymorpha*) is a recent introduction (1996) which now has only a limited distribution in the Lower Lough. As this species expands its range and abundance throughout the Erne system, it may impact significantly on the lake ecology. Water monitoring is undertaken at the deepest portion of Lower Lough Erne with limited samples taken along a gradient towards the main river inflow of the lake.

R01 River Eden

Cumbria, England (Lat 54° 39'N; Long 2° 37'W; NGR 3604 5282)
Sponsor: Environment Agency, North West Region

The river rises south of Kirkby Stephen on the Cumbria/Yorkshire border and flows northwards to Carlisle before discharging to the

Solway Firth. The eastern part of the catchment is drained by short, relatively steep streams from the Pennines; the western part includes tributaries of the Eamont system which arise in the eastern hills of the English Lake District, and the major lakes, Ullswater and Haweswater. The catchment is largely rural, with farming the main industry. There are significant settlements on the upper part of the river at Kirkby Stephen and Appleby-in-Westmorland. Water quality in the upper reaches is classified as good and drinking water is abstracted to supply the city of Carlisle. The river is excellent for salmon (*Salmo salar*) fishing and also supports a sea trout (*Salmo trutta*) run. Many other species of fish are also found, (eg brown trout (*Salmo trutta fario*), grayling (*Thymallus thymallus*), chub (*Leuciscus cephalus*), dace (*Leuciscus leuciscus*), eel, minnow (*Phoxinus phoxinus*), loach (*Barbatula barbatula*), river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromygon marinus*), and brook lamprey (*Lampetra planeri*), stickleback (*Gasterosteus aculeatus*) and bullhead (*Cottus gobio*)). Otters and native crayfish (*Austropotamobius pallipes*) are also found in the Eden catchment. The Eden at Temple Sowerby is within the 'River Eden and Tributaries' SSSI, and the proposed Special Area of Conservation (SAC) under the EC Habitats and Species Directive.

The sampling site is in an upland farming area at an altitude of about 100 m AOD. The surrounding countryside is hilly, with some woodlands, rising to the bare slopes of the Pennine hills to the east. These have been mined for lead and silver in historic times, and gypsum is still extracted. The underlying bedrock is Permo-Triassic Penrith Sandstone, with smaller tributaries of the Eden draining from the surrounding Carboniferous Limestone. The market town of Appleby, with a population of about 3000, is roughly 14 km away by road. Its primary influence on the river is the discharge from the Sewage Treatment Works 16 km upstream, which currently has secondary treatment and, since January 1999, phosphorus stripping of the wastewaters it receives.

The ECN site is at the Eden Bridge in Temple Sowerby, where the A66 trunk road crosses the river.

R02 River Esk

North Yorkshire, England (Lat 54° 28'N; Long 0° 38'W; NGR 4885 5089)
Sponsor: Environment Agency, North East Region

The River Esk rises on the uplands of the North York Moors National Park and is the only major river in the county of Yorkshire which drains directly into the North Sea. The catchment is sparsely populated and without the pressures of industrialisation and urbanisation which affect other rivers in the Region. Open moorland characterises much of the catchment and is an important habitat for a wide variety of wildlife. Within the Esk valley there are six SSSI, two of which extend south and cross the boundary of the Derwent catchment.

The source of the Esk is upstream of Westerdale, where a series of small streams known as the Esklets merge to form the River Esk. Many of these moorland streams are affected by natural 'flushes' of acidity, as well as iron run-off from natural ironstone strata and old mineral workings, making some of these becks an ochreous-orange colour after periods of rainfall. The combination of the two factors restricts the invertebrate fauna in these head-streams. The majority of the River Esk downstream of the Esklets has very good water quality, with a diverse invertebrate fauna dominated by mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), caddis-flies (*Trichoptera*) and other pollution-sensitive groups. This good water quality is also very important in sustaining other species such as salmon, sea trout, dipper (*Cinclus cinclus*) and otter.

The ECN site is at Briggswath, approximately 2 km upstream of the tidal limit. At this point the river is approximately 15 m wide, and in normal summer flows depths vary between 20–30 cm.

R03 River Coquet

Northumberland, England (Lat 55° 21'N; Long 1° 38'W; NGR 4234 6061)

Sponsor: Environment Agency, North East Region

The River Coquet rises at Coquet Head on the Scottish border and flows generally eastward, draining the southern flanks of the Cheviot Hills, finally discharging to the North Sea at Amble. The Warkworth Dam marks the tidal limit.

The River Coquet is an excellent, clean river system of high conservation and ecological value. The River Coquet is designated as an SSSI as part of the National Programme of 27 river SSSI's. Bankside habitats range from woodland-fringed lower river and wooded lowlands through hay meadows, herb-rich valleys and the gravel haughs of lower Coquetdale to the upper moorlands of the Cheviots. This relatively undisturbed environment provides excellent habitats for wildlife including a number of protected species. Within the Coquet catchment there are 10 other SSSI's which directly influence, or are influenced by, the water environment. The principal protected habitats are hay meadows, woodland and the estuary.

The main river supports a healthy and diverse invertebrate fauna of mayflies, stoneflies, caddis-flies and other taxa which are sensitive to pollution. Their presence indicates the absence of chronic pollution. Although the habitat and water quality are suitable for native crayfish, they have never been found by the EA, even though they were reliably reported as being present at Thropton and Felton in 1981.

The ECN site on the Coquet is at Warkworth, approximately 2 km upstream of the tidal limit.

R04 River Exe
Devon, England (Lat 50°48'N; Long 3°31'W; NGR 2936 1016)
Sponsor: Environment Agency, South West Region

The ECN site is at Thorverton weir on the River Exe which drains the Exmoor National Park and is situated above the City of Exeter and the more industrialised sub-catchment of the River Culm. Most of the catchment is populated by isolated farmsteads, hamlets, villages and small towns. The only major urban area upstream of this site is Tiverton. The River Exe rises at a level of 450 m AOD in the wet moorland of Exmoor, then passes through steep-sided valleys with extensive broad-leaved woodland. Further east, tributaries run off the Brendon Hills with the River Haddeo and the major water resource of Wimbleball Reservoir. Further south of these tributaries, towards Tiverton, the floodplain opens out and rolling farmland replaces woodland. The farmland in the catchment of Thorverton weir supports sheep, cattle and dairy farming. All stretches of river above Thorverton weir, except the Riverton canal, have water of good or very good quality suitable for all fish species. The average rainfall for the Exe catchment as a whole is 1097 mm, with a maximum of 2018 mm on Exmoor. Analysis of the flow record at Thorverton shows a mean daily flow of 15.887 cumecs and the river has a relatively 'flashy' flow regime compared with the rest of England.

R05 River Wye
Monmouthshire, Wales (Lat 51°47'N; Long 2°40'W; NGR 3536 2098)
Sponsor: Environment Agency, Wales

The River Wye is one of the largest rivers in Britain. It rises on the Plynlimon mountains at 741 m AOD and flows through several towns, including Rhayader, Builth Wells, Hay-on-Wye, Hereford, Ross-on-Wye and Monmouth, before meeting the Severn Estuary at Chepstow. The total catchment area is 4136 km^2 and the population of 226 000 is centred on the main towns. The River Wye catchment is one of idyllic beauty and unspoilt scenery, ranging from mountainous uplands through intensively farmed agricultural land to the deep, wooded gorge of the lower river. The River Wye itself is designated as SSSI and a candidate Special Area of Conservation; it is one of the most important rivers in Britain in nature conservation terms. Much of the lower valley is designated an Area of Outstanding Natural Beauty (AONB).

The surface water in the Wye and its tributaries is mostly unpolluted and thus much of it is suitable as a source of drinking water and for supporting a salmon and trout fishery. Nevertheless, certain rivers and streams in the upper catchment suffer from acidification and localised pollution problems resulting from inadequate sewerage and agricultural sources also exist.

The Wye is one of the best-known salmon rivers in England and Wales. Shad (*Alosa* spp) and sea lamprey also migrate into the Wye. Other notable fish species include the bullhead, river lamprey and the brook lamprey. The river corridor supports a variety of plant communities, with plants of note being the rare river jelly lichen (*Collema dichotomum*) and extensive stands of river water-crowfoot (*Ranunculus fluitans*). These stands of *Ranunculus* form a habitat of European interest: 'Floating vegetation of *Ranunculus* of plain and submountainous rivers'. Otters, water voles (*Arvicola terrestris*), several bat species (*Microchiroptera*), dippers, sandmartins (*Riparia riparia*), kingfishers (*Alcedo atthis*) and little ringed plovers (*Charadrius dubius*) inhabit the river corridor. The biological quality of the river is generally good and supports some nationally rare or scarce invertebrate species including the mayfly (*Potamanthus luteus*), the freshwater pearl mussel (*Margaritifera margaritifera*), the depressed river mussel (*Pseudanodonta complanata*) and the native white-clawed crayfish. The river also supports several rare species of non-aquatic invertebrates associated with gravel shoals.

The ECN site is situated in the lower reaches of the Wye at Redbrook at an altitude of 15 m, approximately 37 km from its confluence with the Severn Estuary and 219 km from its source.

The river here is fast-flowing and averages 40 m in width and over 1 m in depth.

R06 River Lathkill

Derbyshire, England (Lat 53° 11'N; Long 1° 40'W; NGR 4220 3647)

Sponsor: Environment Agency, Midlands Region

The River Lathkill is located in the Peak District National Park and is designated as SSSI. It is the only river in Britain which rises in, as well as flows through, limestone for its entire length. The upper parts are a winterbourne, and in summer the stream issues from bubble springs lower down the valley. Downstream there are alternately moderately flowing gravelly sections and silted pools, some formed by natural tufa dams, others artificially. In the pools there are abundant submerged plants including species of *Veronica*, *Ranunculus*, *Potamogeton* and *Callitriche*, while faster sections are carpeted with bryophytes, some of which are nationally rare (eg *Cratoneuron commutatum*). There are no direct discharges to the river but the Knotlow cave system has recently been contaminated with sewage effluent and there is concern that this may eventually wash into the river. There are two licensed abstractions of water for fish-rearing purposes and there are concerns over low flows which may affect water quality and the biota; in the summer of 1996 the lower 2 km of the river dried up completely. There was a suspected outbreak of crayfish plague in 1993 and crayfish have not been present in the invertebrate samples since that time.

R07 Cringle Brook

Lincolnshire, England (Lat 52° 50'N; Long 0° 38'W; NGR 4921 3287)

Sponsor: Environment Agency, Anglian Region

Cringle Brook is a tributary of the River Witham, south of Grantham. It is a spring-fed limestone stream, 12 km in length. It has one small tributary, Wyville Brook, flowing into an impounded section comprising two small ornamental lakes whose total area is around 750 m^2. The ECN sampling site is situated in the lower reaches of the Cringle, downstream of the impounded section, where the brook is 5–7 m wide and 10–50 cm deep, flowing over a sand/gravel substratum with a small content of cobbles and infrequent sections of limestone pavement. This stretch is surrounded by a private golf-course,the river channel and adjacent river corridor being generally unmanaged, with extensive bankside tree-cover and no engineering works (eg weed-cutting, dredging or re-profiling) undertaken. The upstream impoundment maintains a year-round flow of little variation, and also buffers the downstream section against mild enrichment by a village sewage treatment works at Skillington and a sewage pumping station at Stoke Rochford. The brook consequently supports a stream fauna of very high diversity, including a resident population of native crayfish and also sustains a rich aquatic flora.

R08 River Frome

Dorset, England (Lat 50° 41'N; Long 2° 09'W; NGR 3890 0867)

Sponsor: Environment Agency, South West Region

The River Frome is essentially a rural catchment of high amenity and ecological value. The upper part of the catchment lies within the Dorset AONB and is characterised by steep-sided valleys. The only large urban area within the catchment is Dorchester (population 15 104). In the upper reaches the river depends on springs and groundwater levels for flows. Many of the steams are winterbournes and the streams cease to flow in summer or are perched where the river goes underground for part of its length. All stretches of river above Holme Bridge have water of good or very good quality suitable for all fish species. Land use in the catchment is typically permanent grassland with dairying or stock rearing, with some cereals and natural wetland habitats. The majority of the upper reaches lies on chalk which produces the high groundwater component of flow. The lower reaches are dominated by sands, gravels and clays. Rainfall in the catchment varies between 850–1100 mm a year. Much of the flow depends on groundwater and the river responds slowly to rainfall events.

R09 Bradgate Brook

Leicestershire, England (Lat 52° 41'N; Long 1° 14'W; NGR 4522 3098)

Sponsor: Environment Agency, Midlands Region

Bradgate Brook is located in the Charnwood Forest area of Leicestershire, important for its Precambrian granitic rocks. The brook

flows through the ancient parkland of Bradgate Park and into Cropston Reservoir. The park is managed as a deer park, has never been agriculturally 'improved' and is designated SSSI. However it was bequeathed to the people of Leicester for their enjoyment and there are public access pressures on the site. There are no discharges to or abstractions from the brook, which supports an invertebrate community of regional importance, including a population of native crayfish.

R10 River Bure

Norfolk, England (Lat 52°43'N; Long 1°21'E; NGR 6267 3198)

Sponsor: Environment Agency, Anglian Region

The River Bure is one of the major rivers flowing through the Norfolk Broads. The sampling site, at Horstead Mill, is in its middle reaches, approximately 40 km from the source of the river, at the limit of navigation, and at an elevation of less than 10 m. Here the river is 17–20 m wide and up to 4 m deep, with a predominantly silty substrate. The surrounding catchment is underlain by Quaternary deposits of Norwich Crag with chalk at depth and superficial glacial till and outwash deposits. Land use in the catchment is predominantly agricultural, especially arable. Due to problems with eutrophication of the Broads, there has been a programme of phosphate stripping at the major sewage treatment works on the Bure since 1986.

Invertebrate monitoring takes place downstream of the Mill where the river is divided into two channels and there is a riffle area of gravel, pebbles and sand and areas of emergent plants (*Sparganium erectum, Glyceria sp.)* at the margins. Macrophyte and diatom monitoring takes place between 0.5–1 km upstream of the Mill at a semi-natural stretch of river away from man-made structures. The substrate is predominantly silty. There is a diverse submerged plant community, including a good cover of *Elodea nuttallii.* Several marginal and emergent species are also present.

R11 Old Lodge

West Sussex, England (Lat 51°03'N; Long 0°05'E; NGR 5457 1294)

Sponsor: Department of the Environment, Transport and the Regions (through the Acid Waters Monitoring Network)

Old Lodge is a stream site within a catchment of 240 ha in Ashdown Forest, south-east England. The altitude of the catchment ranges between 94 m and 198 m. The underlying geology comprises Ashdown sands (Hastings beds) and the catchment soils are typically podsolic. Approximately 15% of the catchment is deciduous woodland, principally around the sampling site. Conifers occupy less than 5% of the catchment, with the remainder classified as heathland vegetation dominated by heather and bell heather (*Erica cinerea*), with abundant stands of bracken (*Pteridium aquilinum*).

There has been no land use disturbance in the catchment for the past 200 years, although severe wind-throw affected many trees after the storms of October 1987.

Old Lodge is also an AWMN site, classified as having moderate-to-high acid deposition. The catchment has been the focus of research into the relationship of acid stream chemistry and biological, particularly invertebrate, populations.

R12 River Stinchar

Strathclyde Region, Scotland (Lat 55° 06'N; Long 5° 00'W; NGR 2085 5822)
Sponsor: Scottish Environment Protection Agency, West Region

The River Stinchar is situated in south Ayrshire. It rises close to Loch Doon and flows for 46 km before entering the Firth of Clyde at Ballantrae. It has a catchment area of 340 km^2 and its average flow is 11.2 cumecs. The catchment is largely rural, with only a few small and scattered communities. Farming is mostly dairy cattle and sheep rearing, and there have been some pollution problems associated with the latter, in particular through spillages of sheep dip chemicals.

The upper part of the catchment is extensively forested with conifers for commercial use. The granitic geology and the maturity of the trees have resulted in low pH values at the uppermost routine sampling point. Part of the flow of the upper reaches of the river is diverted by an aqueduct to feed water into the Loch Braden water supply reservoir. The ECN site is situated in the lowest reach of the river, where the acidity has been buffered by the base cations in the lower part of the catchment.

R13 Lower River Clyde

Strathclyde Region, Scotland (Lat 55° 51'N; Long 4° 14'W; NGR 2595 6644)
Sponsor: Scottish Environment Protection Agency, West Region

The catchment area of the River Clyde is about 2000 km^2 and the river changes in character a great deal in its 121 km journey to the tidal weir in Glasgow. In its upper reaches, it is used to fill the Daer reservoir which supplies drinking water to much of south Lanarkshire; there is also sheep farming and commercial afforestation in this part of the catchment. The river is joined by tributaries of various sizes and quality reflecting the land uses of their catchments; there is much opencast coal mining in some, whilst others are urban or agricultural. The Clyde passes through a fertile valley in its middle reaches where there is extensive market gardening, fruit growing and garden centres. In its lower reaches the river receives a considerable amount of treated sewage effluent from large regional sewage works. The river is quite sluggish in its flow because of the flat landscape. As a result of this and the biochemical oxygen demand (BOD) of the effluents, there is serious oxygen depletion in the lower reaches during the summer months.

The ECN sampling site is situated in the lowest reach, where average flow is 41 cumecs.

R14 Allt a'Mharcaidh

Highland Region, Scotland (Lat 57°07'N; Long 3°51'W; NGR 2869 8050)

Sponsor: Scottish Environment Protection Agency, North Region

Allt a'Mharcaidh is a stream site on the western flank of the Cairngorm Mountains. The catchment area is 998 ha and it drains to the River Feshie, a tributary of the River Spey. The catchment rises from 325 m at the sampling site to 1111 m and is covered by alpine and peaty podsols (60%) and blanket peat (40%). The underlying geology is intrusive biotite-granite of the Lower Old Red Sandstone age. Vegetation is characterised by a heather/fescue grass mixture (90%) with native pinewoods (*Pinus sylvestrus*) (2%) interspersed along the lowest reaches. The catchment comprises part of the Cairngorm NNR and land use is confined to deer grazing. The stream gradient is steep and exposed bedrock, rapids and waterfalls and large boulders characterise the monitored channel section.

Allt a'Mharcaidh is also an AWMN site, classified as having moderate acid deposition.

R15 River Spey

Grampian Region, Scotland (Lat 57°37'N; Long 3°06'W; NGR 3341 8596)

Sponsor: Scottish Environment Protection Agency, North Region

The River Spey rises in the high ground of the Grampian Mountains and flows in a north-easterly direction towards the Moray Firth. It drains a relatively large catchment of 3008 km^2 with a stream network of 36 400 km, of which the main river comprises 157 km. The upper part of the catchment is characterised by its mountain wilderness regions, sheep farming and tourism, whilst in the lower catchment these are complemented by the distilling industry, cattle and arable farming, and related industries. There is restricted commercial forestry on the narrow valley bottoms and steep-sided hills of the upper catchment, but as the valley floor widens it becomes much more extensive (16% of total catchment land use). Most of the Spey catchment is underlain by metamorphic rocks of the Cambrian Period and these are intruded at a number of places by granite plutons and are overlain at the northern end of the catchment by Devonian sandstone. For most of its length the River Spey flows through a wide alluvial plain composed of silts, sand and waterborne pebbles.

The catchment is of great conservation value with 27 SSSI including various woodland, wetland and montane habitats, fossil sites, and various geomorphological features. The river itself is designated SSSI at the Insh Marshes, at the lower section downstream of Fochabers for its unique active braided channel and associated habitats, and at Spey Bay which is of prime importance for its geomorphology. The

River Spey is renowned for its salmon fishing with an estimated input into the local economy of £6 million per annum. The salmon fishery is the subject of much research and fisheries management activity.

R16 River Tweed

Borders Region, Scotland (Lat 55° 36'N; Long 2° 46'W; NGR 3509 6347)
Sponsor: Scottish Environment Protection Agency, East Region

This is a stream site located 80 km from the source of the River Tweed, above Galafoot. The catchment area above this site is 150 000 ha. The catchment rises from 92 m at the sampling site to 400 m and is mainly covered by peaty and humus-iron podsols. The underlying geology of the upper Tweed catchment is of shales, mudstones, slates and greywackes. Land cover types for the entire Tweed catchment are improved grassland (26%), rough grassland (16%), woodland (16%), heather/peatland (10%) and arable (18%) although almost all of the latter is found downstream of this site. The River Tweed has an international reputation both as a salmon river and as an excellent trout water. The Tweed has been designated as SSSI and is recognised as a nationally important example of a relatively nutrient-rich river system showing characteristic hydrological and biological sequences along its length. The upper Tweed has also been designated as a National Scenic Area (NSA) and there is an Environmentally Sensitive Area (ESA) designation covering that portion of the catchment in the central Southern Uplands.

R17 River Eden

Fife Region, Scotland (Lat 56° 20'N; Long 2° 56'W; NGR 3415 7158)
Sponsor: Scottish Environment Protection Agency, East Region

The River Eden drains some 400 km^2 of north Fife, 307 km^2 of which lie upstream of the ECN site at Kemback. The river rises at around 220 m AOD and the catchment is predominantly low-lying. The major land use in the area is arable farming and approximately 76% of the catchment is prime agricultural land with very fertile soils or imperfectly drained brown forest and alluvial types. Underlying geology comprises Devonian and Carboniferous strata, the former including the most productive aquifer in Scotland, the Knox Pulpit formation. Water is abstracted from groundwater, the river and its tributaries for irrigating crops. The Balmalcolm area of the catchment is a designated Nitrate Vulnerable Zone under the EC Nitrate Directive. Although treated sewage is discharged to the river from several small communities and from the town of Cupar, the effect of diffuse inputs from agriculture is believed to be critical to river water quality. There is a modest salmon run to the river and otters are present. The river enters the sea 4 km to the north of St Andrews and its estuary forms the Eden Estuary Local Nature Reserve – an important overwintering site for wildfowl and waders.

R18 River Cree

Dumfries & Galloway Region, Scotland (Lat 54° 57'N; Long 4° 28'W; NGR 2412 5653)

Sponsor: Scottish Environment Protection Agency, West Region

The River Cree has a catchment area of 515.7 km^2, much of which is afforested, and a total river length of 57.5 km. It has become one of the most acidic catchments in south-west Scotland, with pH values as low as 5.0 being recorded occasionally. This raises concerns about its ability to meet the EC requirements for freshwater fisheries and about the survival of the salmon fishery. There are many sewage effluent discharges entering the river along its course, most of which have small flow rates; the largest discharge is from Newton Stewart. In the early 1980s, large stretches of the river were subject to excessive weed growth, believed to be due to the aerial application of fertilisers over large tracts of forest. The mean pH at Newton Stewart is 6.5, with lower mean pH levels upstream.

R19 River Faughan

County Londonderry, Northern Ireland (Lat 55° 01'N; Long 7° 15'W; IGR 2476 4193)

Sponsor: Department of the Environment for Northern Ireland

Rising on the north-western slopes of the Sperrin Mountains above Claudy, the Faughan flows in a general north-westerly direction, augmented by numerous tributaries and eventually discharging to Lough Foyle. There are no significant urban influences until the river flows through the Drumahoe industrial estate.

Approximately 40 km long, the river has a catchment area of just under 300 km^2. The River Flow Gauging Station at Drumahoe records flow for more than 95% of the catchment upstream of the ECN site, which is located at Mobuoy Bridge.

The geology of the upper reach consists predominantly of thin deposits of peat overlying schists and quartzite from the upper Dalradian period. This results in a typically 'flashy' runoff characteristic. Further downstream, the lithology changes to boulder clay (till) with significant deposits of sands, gravels and alluvium in the river plain. The underlying solid geology varies to include grits and slates with a thin band of Dungiven Limestone.

The steep valley slopes and upper reaches have little capacity to store and transmit groundwater, while the lower reach and river plain may be classified as moderately permeable solid aquifers. In particular, the sand and gravel deposits, overlying fractured grits and slates, are vulnerable to surface impacts and form an important source of base river flows.

The river is a renowned salmon and sea trout fishery with approximately 20 km of prime angling water which includes the tidal stretch downstream of Campsie. It also supports a significant

brown trout fishery in its upper reaches and tributaries. In 1996, 13 000 salmon were recorded entering the system. The River Faughan is designated salmonid under the EC Freshwater Fish Directive and its chemical quality is good to fairly good. Biological quality is highly variable due to intermittent localised pollution.

R20 Garvary River

County Fermanagh, Northern Ireland (Lat 54°31'N; Long 7°59'W; IGR 2009 3630)
Sponsor: Department of the Environment for Northern Ireland

Located to the north of Lower Lough Erne, the Garvary River has its source in the outflows from Loughs Vearty and Tullyasiddagh. It flows in a general south-easterly direction, augmented by the Crossowen River and the outflow from Lough Scolban, and eventually discharges to Lower Lough Erne. Approximately 7 km long, the river has a catchment area of 35.5 km^2 of which around 5% is lake surface. At the ECN site, the river is 2.5–3 m wide and 30 cm deep with a few holding pools around 60 cm deep.

The drift geology of the catchment consists mainly of peat and bedrock at or near the surface which some glacial till and small amounts of sand and gravel. The solid geology is mainly mica schist of the Moinian period.

In its upper reaches, the river flows through moorland and peat bog. Soils in the catchment are peats and gleys with poor drainage capacity, supporting a vegetation cover of rough pasture, bracken and heather. The upper part of the catchment supports low intensity sheep grazing, while downstream the land use is predominantly improved grassland.

Although the river has not been designated under the EC Freshwater Fish Directive it has excellent water quality both chemically and biologically, and it is a very important nursery area with high densities of juvenile trout and salmon. Its banks have many trees (mainly alder, willow (*Salix* spp) and hazel (*Corylus avellana*)) which provide adequate shading for the juvenile fish. The river is not suitable for angling and does not have stocks of takable fish. Wildlife found in the river corridor include mallard (*Anas platyrhynchos*) and dragonflies (Odonata).

R21 River Bush

County Antrim, Northern Ireland (Lat 55° 12'N; Long 6°31'W; IGR 2940 4405)
Sponsor: Department of Agriculture for Northern Ireland

The River Bush enters the Atlantic Ocean close to the Giants Causeway on the north Antrim coast of Northern Ireland. Rising in the Antrim hills at 480 m AOD, for most of its length the river flows through a fertile valley devoted to grassland-based agriculture with limited arable cropping. The underlying geology is basalt and the

water is slightly alkaline with magnesium making an unusually large contribution to total hardness. The river supports indigenous stocks of Atlantic salmon and brown trout, but it is the salmon population which is of the greater interest. Bush salmon have been the focus of long-term studies on salmon ecology and on the techniques suitable for managing salmon populations. A fish-trap on the river at Bushmills, some 3.5 km from the sea, enables ascending adult fish and returning juvenile salmon smolts to be intercepted, counted and sampled. This work has continued since 1973 and is accompanied by annual assessments of fry survival in the main spawning areas of the river. In addition to the river being part of the ECN network, it is an index river of the International Council for the Exploration of the Sea (ICES) which integrates the results with those of other salmon research programmes in the north-east Atlantic.

R22 Trout Beck

Cumbria, England (Lat 54° 42'N; Long 2° 22'W; NGR 3758 5335)

Sponsors: Natural Environment Research Council and English Nature

Trout Beck is a headwater stream of the Tees which drains Great Dun Fell, Hard Hill and Knock Fell in the North Pennines. The ECN sampling site is at 535 m AOD and the catchment above this covers 1146 ha, rising to 848 m AOD. The geology is alternating strata of Carboniferous limestones, slates and shales. Blanket peat covers 90% of the catchment with skeletal soils towards the fell tops and small areas of limestone soils and alluvial soils. Vegetation is dominated by heather, cotton grass and *Sphagnum* moss. The catchment lies in Moor House NNR, which is owned by English Nature. Discharge is measured at a Compound Crump Gauging Station operated by the EA. The pH of Trout Beck averages 6.2 although there are wide fluctuations associated with the discharge. The site has a long history of ecological research. Trout Beck is the first ECN Freshwater Site with its catchment entirely within an ECN Terrestrial Site.

R23 River Coln

Gloucestershire, England (Lat 51° 41'N; Long 1° 42'W; NGR 4204 1988)

Sponsor: Environment Agency, Thames Region

The River Coln rises at an altitude of about 200 m AOD near Sevenhampton in Gloucestershsire and flows from the limestone Cotswold Hills in a south-easterly direction to Lechlade, where it joins the River Thames at an altitude of about 75 m AOD. There are no major tributaries. The sampling site is located in Lechlade about 70 m above the confluence with the Thames. The source of the river is in the Inferior Oolite aquifer in which it flows for the first few kilometres, but most of the river runs on the Great Oolite aquifer. Both limestone aquifers are sources for water abstraction; a total of 55 million litres per day are consented from the catchment.

The river crosses Oxford Clay before running into the Thames. The catchment is mostly rural, with farming as the main industry. The upper catchment is mainly grazing land, and there are large areas of deciduous woodland in the south-west. The upper two-thirds of the catchment is within the Cotswold AONB, and around Fairford the river has been designated as a Nitrate Sensitive Area.

There are no large conurbations on the upper catchment, although Cheltenham, from where surface water drains into limestone above the river's source, has a population of over 100 000. The Coln catchment supports a population of around 9000. The main sewage inputs to the river are from works at Andoversford, Bibury and Fairford. Bibury trout farm has the largest discharge into the river, although most of this is 'on-line' through fish-ponds. The river has been subject to various enhancement schemes to improve ecology and fisheries. Water quality was recorded as 'good to fair' in 1995. The classification varies throughout the river, due to the effects of both discharges and low flows.

The biological quality of the river is very good. The river supports a brown trout fishery with good spawning beds. Natural populations of grayling also exist. Native crayfish have been recorded but not since 1991; populations of the introduced American signal crayfish (*Pacifastacus leniusculus*) are also present. Several pollution-sensitive caddis-fly and mayfly families have been found, along with true-bugs, beetles and snails.

R24 River Lambourn

Berkshire, England (Lat 51°25'N; Long 1°21'W; NGR 4453 1691)

Sponsor: Environment Agency, Thames Region

The River Lambourn rises near the village of Lambourn in the chalk of the Berkshire Downs at an altitude of about 152 m AOD. It is 26 km long and flows through the Kennet Valley in a south-easterly direction to Newbury where it joins the River Kennet at an altitude of about 85 m AOD. There is one important tributary, the Winterbourne Stream, which flows into the Lambourn from the north-east, just upstream of Newbury. The sampling site is located at Bagnor), 5 km above the confluence with the Kennet, at an altitude of about 80 m. Flow ranges between 1.2 and 4.1 cumecs.

The catchment is mostly rural, with mixed farming as the main industry, and there are extensive deciduous woodlands on the catchment boundary. The river forms part of the proposed Kennet and Lambourn floodplain SAC under the EC Habitats Directive. Most of the river is designated SSSI.

There are no large conurbations on the upper catchment but the river flows through Newbury, a town with a population of about 35 000, which provides inputs of surface water run-off. Ten

kilometres from the source, the river receives input from East Shefford sewage works; the only other significant input is from Lambourn Trout Farm. Water quality in the Lambourn is good; the river is classified as GQA biological class 'b' and chemical class 'A'.

The river corridor is notable for reed beds and willow stands and the floodplain provides important feeding grounds for snipe (*Gallinago gallinago*) and water rail (*Rallus aquaticus*). There are good, extensive gravel spawning areas for salmonids; the river supports one of the best and most productive fisheries for brown trout in the area, with natural populations of grayling also present. The Lambourn is in the top 10% for England and Wales for the number of macro-invertebrate families recorded during the GQA survey; five nationally rare species of invertebrates are found in the river. Native crayfish have not been recorded in recent years, although they are present downstream in the Kennet; however introduced American signal crayfish are present.

R25 River Eden

Kent, England (Lat 51° 10'N; Long 0° 10'E; NGR 5520 1438)

Sponsor: Environment Agency, Southern Region

The Eden is a tributary of the River Medway in Kent. It rises south of Caterham and flows eastward through Wealden clay to join the River Medway near Penshurst. Its main tributaries are the Gibbs Brook, Eden Vale Stream, Eden Brook, and the Felbridge Water. The Eden catchment is largely rural and agricultural although much of the dairy farming, which predominated previously, has now declined and has been replaced by mixed farming. The sampling site is east of Penshurst in a flat valley surrounded by agricultural land which is not wooded, and is upstream of a sluice where the river is slow flowing. There is no industry in the area.

Water quality in the Eden is mainly classified as GQA class C, although the headwaters near Oxted are class D. The river receives treated sewage effluent from two Southern Water Services Limited Sewage Treatment Works, serving Edenbridge and Oxted respectively; the stretches receiving these effluents are both subject to EC Urban Water Treatment 'Sensitive Waters' investigations. There are other, much smaller private sewage treatment works throughout the catchment. The river and its tributaries support coarse fisheries. Average flows at Penshurst range from 3.9 cumecs in January to 0.49 cumecs in July.

R26 River Ewe

Highland Region, Scotland (Lat 57° 45'N; Long 5° 36'W; NGR 1858 8806)

Sponsor: Scottish Environment Protection Agency, North Region

The River Ewe, in Wester Ross, is a short stretch of river running north-westwards out of Loch Maree into the sea at Poolewe. The

large upland catchment (441 km^2), which includes Loch Maree and Loch Ewe, is mainly peaty moorland managed predominantly for deer grazing, with some hill sheep farming but negligible arable farming. It is well known for its populations of feral goats. Land rises to over 900 m AOD on a number of mountains including Slioch and Ben Eighe. Average annual catchment rainfall is 2272 mm and long-term average flow at the Poolewe gauging station is 29.6 cumecs.

The Ewe catchment is as close to pristine as is possible on the Scottish mainland and, unusually for this part of Scotland, it has no discharges from intensive fish farming. Parts of the catchment are of national scenic and conservation interest and have been designated as NNR and NSA. There are large areas of deer forest and protected woodlands of Scots pine (*Pinus sylvestris*) and native oak (*Quercus petraea*). There is one small-scale hydroelectric scheme on a tributary flowing into Loch Maree; two further small schemes are proposed. The River Ewe and Loch Maree are important for their salmonid fisheries, but the decline of the trout fishery in Loch Maree is a well-recorded phenomenon which is under investigation by the SOAEFD; it is regarded as indicative of such declines generally on the west coast of Scotland.

Table 1. Supporting agencies and sites in ECN

Agency	Sites/support	Site type
Biotechnology & Biological Sciences Research Council	• 2 Terrestrial sites (North Wyke & Rothamsted)	Lowland grassland & arable
Countryside Council for Wales, (jointly with Welsh Office)	• 1 Terrestrial site (Y Wyddfa/Snowdon NNR)	Upland grassland
Department of Agriculture for Northern Ireland	• R21 Bush • L17 Lough Erne • L16 Lough Neagh • 1 Terrestrial site (Hillsborough)	River site Standing water site Standing water site Lowland grassland
Department of the Environment, Transport & the Regions (through its Acid Waters Monitoring Network)	• R11 Old Lodge • L08 Llyn Llagi • L09 Lochnagar • L07 Scoat Tarn • Support for Central Co-ordination Unit	River Site Standing water site Standing water site Standing water site
Department of the Environment for Northern Ireland	• R19 Faughan • R20 Garvary	River site River site
English Nature	• Site & facilities at 1 Terrestrial site (Moor House & Upper Teesdale)	Upland grassland & blanket bog

Environment Agency	• R09 Bradgate Brook	River Site
	• R10 Bure	River Site
	• R23 Coln	River Site
	• R03 Coquet	River Site
	• R07 Cringle Brook	River Site
	• R01 Eden (Cumbria)	River Site
	• R25 Eden (Kent)	River Site
	• R02 Esk	River Site
	• R04 Exe	River Site
	• R08 Frome	River Site
	• R24 Lambourn	River Site
	• R06 Lathkill	River Site
	• R05 Wye	River Site
	• L02 Hickling Broad	Standing water site
	• L01 Upton Broad	Standing water site
	• L03 Wroxham Broad	Standing water site
Forestry Commission	• 1 Terrestrial site (Alice Holt Forest)	Woodland
Ministry of Defence	• 1 Terrestrial site (Porton Down)	Chalk grassland
Ministry of Agriculture, Fisheries & Food	• 1 Terrestrial site (ADAS Drayton) • Soil Survey & monitoring at English & Welsh terrestrial sites	Mixed farming
Natural Environment Research Council	• R22 Trout Beck (Moor House)	River site
	• L05 Esthwaite Water	Standing water site
	• L06 Loch Leven	Standing water site
	• L04 Windermere	Standing water site
	• 2 Terrestrial sites: – Moor House & Upper Teesdale; – Wytham (site provided by Oxford University)	 Upland grassland & blanket bog Woodland & arable
	• ECN Central Co-ordination Unit	
Scottish Environment Protection Agency	• R14 Allt a'Mharcaidh	River site
	• R18 Cree	River site
	• R17 Eden (Fife)	River site
	• R26 Ewe	River site
	• R13 Lower Clyde	River site
	• R15 Spey (Fochabers)	River site
	• R12 Stinchar	River site
	• R16 Tweed	River site
	• L13 Loch Davan	Standing water site
	• L15 Loch Dee	Standing water site
	• L12 Loch Katrine	Standing water site
	• L14 Loch Kinord	Standing water site
	• L10 Loch Lomond	Standing water site
Scottish Office Agriculture, Environment & Fisheries Dept	• 2 Terrestrial sites (Glensaugh Research Station & Sourhope Research Station)	Upland grassland Upland grassland
Welsh Office (jointly with Countryside Council for Wales)	• 1 Terrestrial site (Y Wyddfa/ Snowdon NNR)	Upland grassland

Operation of ECN

ECN operates by consensus of its participating agencies, each of which is represented on the ECN Steering Committee, the body responsible for the main policy decisions affecting the network; the Steering Committee normally meets annually. The Working Groups which were instrumental in developing the technical and statistical elements of the network have been amalgamated to form a joint Statistics and Technical Advisory Group (STAG) which reports to the Steering Committee. NERC provides the day-to-day management of the network by providing and supporting the ECN Central Co-ordination Unit (CCU) which is responsible for standardising procedures and for co-ordinating data collection and management. The CCU has a staff of five and a half: the ECN Co-ordinator, a statistician, a data manager, an assistant data manager, a half-time assistant data manager and an Information Analyst, all of whom are staff members of the Institute of Terrestrial Ecology. At each operating site, a sponsoring agency provides a Site Manager who is responsible for organising the timely collection and initial processing of data according to the agreed protocols, and for transmission of the data to the ECN data manager in an agreed format

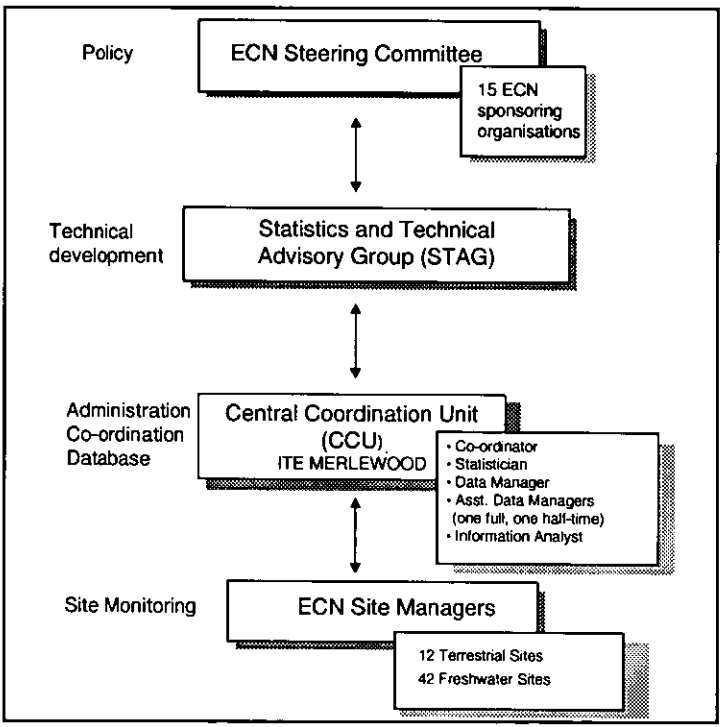

Figure 2. The current organisation of ECN

J. M. Sykes & others
ECN Co-ordinator 1992–95

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Chapter 2 ECN CORE MEASUREMENT PROTOCOLS

The Protocols for ECN's freshwater core measurements contain detailed information on the rationale for the measurement and the procedures to be followed for the sampling location, sampling, treatment of samples and data collection. They also detail the equipment to be used. In comparison with core measurement Protocols for ECN's terrestrial sites (Sykes & Lane 1996), those for freshwater sites are somewhat less prescriptive because they have had to take into consideration existing and sometimes long-standing sampling procedures in operation at the sites. In many cases ECN's freshwater sites have existed for several years as sampling sites either for other research programmes or have been used to meet statutory requirements for water quality testing. However, the procedures themselves, and their quality control and assurance, have to meet rigorous standards and would not be acceptable to ECN were they to fall short of these requirements. Historic and reliable records from such long-established sites provide added value to ECN.

Measurements other than those which follow have been considered for inclusion as core measurements but have been rejected as being technically or financially impractical or as being too difficult to prescribe for the different conditions existing at the range of ECN sites. It would, for example, have been desirable to have a regular record of fish populations. In this case site operators are encouraged to collect such information as is possible, especially in relation to the location used for the collection of other ECN data, and to submit it to the ECN CCU. Examples of acceptable methods for the collection of data on fish populations are those given in Patrick *et al.* (1991).

Wherever possible, Protocols already published for ECN's terrestrial sites are also used at the freshwater sites, sometimes with minor modification, for example those relating to 'Surface Water Discharge' and to aspects of the handling of water samples. Although the collection of meteorological data has not been specified as a core measurement at freshwater sites, it is nevertheless recognised as an important adjunct to the other core measurements. It is recommended that wherever possible the Protocols for 'Automatic Weather Station' (Sykes & Lane 1996, pp 38–44) and 'Standard Meteorological Observations' (Sykes & Lane 1996, pp 45–46) should be implemented at freshwater sites.

The dangers associated with working near, on, or in water are well known and are subject to statutory Health and Safety Regulations as well as to additional safety measures required by individual organisations. Similarly, the dangers associated with the handling of certain chemicals potentially or actually hazardous to health are subject to statutory control and advice on their handling. All such

safety measures must always be followed; particular dangers relating to individual core measurements are stressed in the following Protocols.

The core measurements are summarised in Table 2.

References

Patrick, S., Waters, D., Juggins, S. & Jenkins, A. 1991. *The United Kingdom Acid Waters Monitoring Network: Site descriptions and methodology report.* London: ENSIS Ltd.

Sykes, J.M. & Lane, A.M.J., eds. 1996. *The United Kingdom Environmental Change Network: Protocols for standard measurements at terrestrial sites.* London: The Stationery Office.

Table 2. Summary of Freshwater Core Measurements and their recording frequency

		Recording frequency[1]			
		Running waters[2]		Standing waters[2]	
		Recommended	Minimum	Recommended	Minimum
Core measurement					
a) Physical and chemical measurements					
Manual sampling	(FWC)	W	M	F	Q
Automatic Measurements	(FWA)	H	H	H	H
Surface Water Discharge	(FWD)	15 min	30 min	n/a	n/a
b) Biological measurements					
Phytoplankton	(FPP)				
Chlorophyll *a*		W	M	F	Q
Species		n/a	n/a	F	Q
Aquatic macrophytes	(FMA)	Y	Y	2Y	2Y
Epilithic diatoms	(FDT)	3xY	Y	3xY	Y
Crustacean zooplankton	(FZP)	n/a	n/a	F	Q
Macro-invertebrates	(FIN)	3xY	2xY	3xY	Y

Notes

[1] Recording frequency abbreviations:

15 min	every 15 minutes
30 min	every 30 minutes
H	hourly
W	weekly
F	fortnightly
M	monthly
Q	quarterly
Y	yearly
2xY	twice yearly
3xY	three times yearly
2Y	every 2 years
n/a	not applicable

[2] 'Standing water' and 'running water' are used in the text as generic terms to cover more local usage such as broad, lake, loch, lough, and river, brook, beck, burn, stream, respectively. Occasionally, the generic and local terms are used interchangeably.

FWD Protocol

SURFACE WATER DISCHARGE

Aim

The continuous recording of stream or river water discharge at selected sites.

Rationale

The impact of environmental change is likely to bring about a response in hydrological conditions at a site. The water balance at any location is controlled by climate, vegetation cover and soil properties. Any change in the external climate or in the internal structure of the soil-vegetation system of a catchment will be reflected in changes in site hydrology. This may involve changes in evaporation, in soil moisture levels, and in the amount of run-off from the site. Surface water discharge is an important component of catchment hydrology and at relatively pristine sites may provide a sensitive indicator of environmental change. At other sites, extraction of water from and discharges to rivers will affect flow but at all sites flow is an essential measurement in the calculation of changes in loads of nutrient elements and pollutants from catchments.

Method

Equipment

The measurement of flow in rivers will be carried out using a permanently installed control structure or suitable velocity area method.

Location

The complete installation comprises an approach channel, a measuring structure, and a downstream channel. The condition of each of these three components affects the overall accuracy of the measurements. In selecting a suitable river section particular attention should be paid to the following:

- the adequacy of length of channel of regular cross-section available;
- the regularity of the velocity distribution over the cross-section of the approach channel;
- the avoidance of a steep channel if possible;
- the effects of any increased water levels upstream due to the structure;
- the impermeability of the ground into which the structure is to be founded;
- the necessity for flood banks to contain the maximum discharge to the channel;
- the stability of the channel downstream of the structure.

Full details are available in BS 3680 (BSI 1965).

Operation

The operation of the measuring section will conform with BS 3680. A digital logger will record stage (in metres) and flow (in cumecs), preferably at 15 min intervals but at not less than 30 min intervals. Data quality control will be carried out by site staff in accordance with the British Standard. The results of all checks (calibrations, changes and maintenance) recorded at the measuring section will be sent to the CCU for inclusion in the ECN database where appropriate.

Reference

British Standards Institution. 1965. *BS 3680. Methods of measurement of liquid flow in open channels. Part 3. Stream flow measurements.* London: BSI.

Authors

T.P. Burt, R.C. Johnston & R. Owen

FSP Protocol

RECOMMENDED SAMPLING PROCEDURES FOR WATER CHEMISTRY

Aim

To provide guidelines for the sampling procedures to be used at ECN freshwater sites.

Rationale

Standardisation of the methods used for sampling and storage of water samples is desirable for a network of geographically dispersed sites using different analytical laboratories. However, participating laboratories may already have well-established sampling protocols which have been demonstrated to give satisfactory results and which are subject to quality control checks. Such established procedures are acceptable to ECN and the following should therefore be regarded only as a guide to good practice. Where acceptable practices are already in place but differ from those set out below, detailed information on differences should be sent to the CCU.

A detailed discussion of the principles of sampling are given in HMSO (1980), to which reference should be made.

Method

GENERAL CHEMISTRY

Sample containers

Sample bottles are normally either polyethylene or borosilicate glass, though for certain determinands (see Appendix 1, page 53) one or other material is preferred. The capacity of each bottle should be adequate to provide a sufficient volume of water for the required analysis. The containers may also require specific pre-treatment or particular storage conditions or additives for certain determinands. Reference should be made to the appropriate Section of HMSO (1980).

Preparation

Bottles should be washed in a recommended laboratory detergent (eg Decon®90) and thoroughly rinsed in tap water or de-ionised water as appropriate.

Sampling

- **Running waters**
  The preferred method is by hand, taking the sample directly into the sample bottle after wading upstream to the sampling point and reaching upstream to take the sample. Rinse out the bottle with river water by half-filling, shaking vigorously with the stopper in place and discarding the rinse-water before final filling.

Where direct sampling by hand is not possible an appropriate collection device may be used according to the method of analysis, (eg a stainless steel can or Casella Sampler), which should be rinsed out with river water from the site before filling the sampling bottle. Metal devices should not be used where the sample is to be analysed for metals.

- **Standing waters**
  For purposes of establishing the chemistry of outflowing waters it may be adequate to sample at the outlet or abstraction point and to comply with the procedures outlined above for running waters. For certain determinands, (eg temperature and dissolved oxygen profiles), it will be necessary to sample from a boat using an appropriate collection device or direct-measuring instrument whilst complying with appropriate safety procedures.

Method TRACE METALS

Sample containers

Refer to the appropriate Section of HMSO (1980). Normally only polyethylene bottles are used to collect a sample separate from that used for General Chemistry but note, for example, that samples for analysis of mercury should be stored in glass containers.

Preparation

Sample containers for most trace metals should be acid-washed (eg 10% nitric acid) in the laboratory. There are, however, specific requirements for some determinands (eg mercury), and reference should be made to HMSO (1980). Precautions should be taken to avoid subsequent contamination by sealing the container in a polythene bag.

Sampling

Running waters
Remove the container from the protective polythene bag. Sample by hand as for General Chemistry above, but where direct sampling is not possible an appropriate collection device must be used. A polythene bucket can be used; this is rinsed with river water before being filled again to rinse the bottle and finally to collect the sample. Any collection device such as a polythene bucket should be used exclusively for environmental sampling and not for effluents and such devices should be kept between sampling in large polythene bags to avoid contamination. Collection devices should be returned to the laboratory for cleaning after use in each sampling.

FSP Protocol

Filled sample containers should be replaced inside the protective polythene bag and returned immediately to the laboratory.

- **Standing waters**
  Remove the container from the protective polythene bag. For purposes of establishing the chemistry of outflowing waters it may be adequate to sample at the outlet or abstraction point and to comply with the procedures outlined above for running waters. If working from a boat, surface waters should be sampled similarly whilst complying with appropriate safety procedures.

Method

TRACE ORGANICS/PESTICIDES

Sample containers

Only glass bottles should be used.

Preparation

Bottles should be washed initially with a warm solution of aqueous detergent (eg Decon®90). Rinse thoroughly with hot tap water and rinse again with high grade deionised 'organic scavenged' water. Dry in an oven. Finally, rinse with an appropriate solvent (eg hexane or acetone, depending on the determinand). Allow the solvent to evaporate.

Close the bottle and seal in a polythene bag. Label with the following information (unless the stock of prepared bottles is to be used in a short time):

- determinand for which the bottle may be used;
- date of bottle preparation;
- use-by date;
- name of the person preparing the bottle.

Bottles should in any case be used within 3 months of preparation.

Sampling

- **Running waters**
  Sample by hand as for General Chemistry above. Where necessary, a stainless steel collection device may be used and this should be rinsed with water from the river before collecting more water to rinse and fill the sample bottle.

- **Standing waters**
  For purposes of establishing the chemistry of outflowing waters it may be adequate to sample at the outlet or abstraction point and to comply with the procedures outlined above for running waters. If working from a boat, surface waters should be sampled similarly whilst complying with appropriate safety procedures.

LABELLING

It is essential to ensure secure and adequate labelling of all sampling containers and the proper recording of all appropriate site information including:

- site name/code;
- date;
- time;
- sampling personnel;
- water temperature;
- water turbidity;
- water colour;
- weather at time of sampling.

Where existing labelling systems and/or quality control systems are already in operation it will be necessary to ensure that they meet these minimum requirements for ECN purposes.

STORAGE

In general, storage temperature should be between 1°C and 4°C and analysis should be carried out as soon as possible after collection. Storage conditions relevant to particular determinands are given in Appendix 1 (page 53) and further information in HMSO (1980). If samples have to be sent to another location for analysis, the period when samples are out of cold storage should be minimized, for example by specifying next day delivery and not despatching on a Friday.

Where filtering is necessary, reference should be made to the procedures adopted at ECN terrestrial sites (Adamson 1996).

Author

R. Owen

References

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Her Majesty's Stationery Office (HMSO). 1980. *Methods for the examination of waters and associated materials. General principles of sampling and accuracy of results.* London: HMSO.

Appendix I Summary of sample containers and storage conditions for waters

Determinand	Container	Storage Conditions[1]
Acidity	G	Fill bottle to leave no air space. Store in cool dark place[7]
Alkalinity		Fill bottle to leave no air space. Store in cool, dark place[7]
Aluminium		Add 20 ml 5M HCl /litre of sample
Ammonia		See nitrogen
Arsenic	P or G	Add 2 ml 6M HCl/litre of sample
Biochemical oxygen demand[2]		Fill bottle to leave no air space. Store at 4°C in dark[7,8]
Cadmium		Add 2 ml 10M HCl/litre of sample
Calcium	P	Add 2 ml 5M HCl/litre of sample
Chloride	P or G	No special conditions needed
Chromium	P	By AAS – 2 ml/litre of sample. 50% (V/V) HCl by spectrophotometry – 2 ml/litre of sample. 30% (V/V) diluted HNO_3 (d_{20} 1.42)
Copper		Either 2 ml 50% (V/V) HCl/litre of sample or 1 ml HNO_3 (d_{20} 1.42)/litre
Dissolved oxygen[2,6]		Fill bottle to leave no air space. Analyse on site or 'fix' sample by adding manganese and alkaline iodide-azide reagents, then store in dark at 10–20°C for no more than 24 hours[7]
Electrical conductivity		Fill bottle to leave no air space. Store at 4°C[7, 8]
Iron[6]		Add 20 ml 5M HCl/litre of sample[9]
Lead		Add 2 ml 5M HCl/litre of sample
Magnesium		Add 2 ml 5M HCl/litre of sample
Manganese		Add 20 ml 5M HCl/litre of sample[9]
Mercury (non saline samples)	G	Add HNO_3 to give a pH of 1, and sufficient $K_2Cr_2O_7$ to maintain excess until analysis starts[5]

continued...

Determinand	Container	Storage Conditions[1]
...continued		
Metals[3]		
• total	P (d)	This depends on the method used and the metals expected to be present. The usual preservative treatments are either to add 20ml of 5M HCl/litre of sample, or to add 2–10 ml HNO_3/litre of sample: but be guided by the conditions for the most sensitive metal likely to be present. If necessary take two or more samples where preservation techniques are incompatible. If the sample is liable to react with air see note (9)
• total filtrable	P	Filter on site and add 2–10 ml HNO_3/litre of filtrate
Nickel	P	2 ml/litre of sample 50% (V/V) HCl
Nitrogen		
• ammoniacal[2,6]	P or G	If both free and combined ammoniacal nitrogen are required, fill bottle to leave no air space. If only total ammoniacal nitrogen is required, add HCl or H_2SO_4 to give a pH of 2. (e). Store at 4°C[7,8]
• Kjeldahl[2,6]	P or G	Unless free ammoniacal nitrogen is also required add H_2SO_4 to give a pH of 2[5]. Store at 4°C[8]
• nitrate[2]	P or G	Store at 4°C[8]
• nitrite[2]	P or G	Store at 4°C[8]
Organic carbon total	G	Fill bottle to leave no air space. Sample preservation is dependent on the method used. Store at 4°C. For some methods addition of HCl to give a pH of 1–2 is required, for others the use of hydrochloric acid is barred[7,8]
Sodium		No special conditions needed
Sulphate	P or G	Store at 4°C. (If sulphide and/or sulphite present, fill bottle to leave no air space)[7,8]
Solids		
• suspended[2]		No generally-suitable procedure. Analyse as soon as possible
• total		Store at 4°C[8]
Turbidity[2]		No generally-suitable procedure. Analyse as soon as possible
Zinc	P[4]	Either 2 ml/litre of sample 50% (V/V) HCl or 1 ml/litre of sample HNO_3 (d_{20} 1.42)

Notes

P = polyethylene
G = borosilicate glass

(1) It is essential to ensure that the storage conditions selected, including the use of cooling, do not adversely affect the performance of the analytical method.

(2) These determinands are often particularly liable to instability, and it will often be important to take special steps to minimise the time between sampling and analysis.

(3) The term 'Metals' includes the following: Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, Sr, Sn, U, V and Zn. The container and method of preservation quoted in the table are thought to be generally useful for this group of metals. However, other preservation procedures may also be satisfactory. When other procedures are given in analytical methods for metals in the above group published by the Standing Committee of Analysts, these have been included under the individual metals in the table.

(4) Contamination of samples by zinc and other metals leached from plastics has been reported. If in doubt check bottles using distilled water and the desired preservative before use. Discard unsuitable bottles.

(5) If not negligible, note the volume of preservative added or the resultant volume change.

(6) Aerate the sample as little as possible during the filling of the sample bottle.

(7) If no air space is left in a glass bottle, care should be taken to prevent the bottle heating and so generating enough pressure that it bursts.

(8) Care should be taken to prevent accidental freezing in glass bottles.

(9) If iron II or manganese II, or other easily oxidized metals in lower oxidation states are to be determined by oxidation state rather than as total metal, it may be necessary to completely fill bottles (see notes (7), and (8) above). For some highly reactive waters the bottles may need to be filled with inert gas prior to sampling to avoid oxidation during filling.

PHYSICAL AND CHEMICAL VARIABLES

Aim

Collection of samples from standing and running waters (or automatic recording where appropriate) for the measurement of environmentally important physical variables and for the analysis of cations and anions.

Rationale

The justification for the variables selected for measurement in this ECN protocol for freshwater physical and chemical variables is provided in the Introduction to this volume under the heading 'Variable selection' (see page 13). In general the variables have been selected because they are expected to indicate the possible causes and consequences of environmental change in the aquatic environment. Aquatic systems can be considered as consisting of a series of 'master variables' common to all freshwaters, changes in which may significantly affect the system as a whole. Other variables are mainly measures of chemical concentrations which are susceptible to changing inputs and to biogeochemical processes; in addition there are biological components of the systems which are dealt with in other protocols.

Method

Variables to be measured and frequency of measurement

A list of the selected variables to be measured at running and standing water sites is provided in Appendix I of this protocol (page 58), together with recommended and minimum frequencies of measurement. Although there are a few exceptions, most of the variables are common to both running and standing water sites but their frequency of measurement is usually greater at the former. It is anticipated that frequency of sampling will, in practice, commonly exceed the specified minimum frequency. Detection limits for the variables are specified in Chapter 3 (pages 98–99). Water level should be recorded at the same time as the sample is taken for chemical analysis.

Sampling – manual (FWC)

Most variables will be determined from analysis of water samples collected and handled by the methods recommended in the ECN FSP protocol (page 49) 'Recommended sampling procedures for water chemistry' which is intended as a Guide to Good Practice. The document deals with containers, their preparation, use, labelling and storage for both running and standing waters in relation to general chemistry, trace metals, trace organics and pesticides. A widely-accepted text is referenced in the FSP protocol as a source document for the principles involved.

Should operational constraints cause any deviations from the procedures recommended in the ECN protocol, sites must send details of such deviations to the CCU.

Where manual methods are used in the field for physical determinations, (ie pH, temperature, conductivity, turbidity, dissolved oxygen), it is essential that procedures are in place for regular calibration of instruments and quality assurance.

Sampling – automatic (FWA)

A number of both commercially available and research instruments may be used at ECN sites for measuring and recording physical variables in both running and standing waters. Variables commonly measured are pH, temperature, conductivity and turbidity. Instruments usually measure at frequent intervals and record summary values at less frequent intervals; hourly summary values will be reported for ECN purposes. Specifications for sensors and their recording parameters should be discussed with the CCU before installation.

Instruments will be located centrally in standing waters and at convenient, agreed locations in running waters to coincide as far as possible with other ECN measurements.

Procedures for chemical analysis

Laboratories of organisations participating in ECN already have well-established protocols for chemical analysis which are subject to internal quality control (QC) procedures and are accredited to formal quality assurance (QA) schemes or participate in internal or inter-laboratory checks on quality. It is therefore impractical and unnecessary to prescribe either the methods or instruments to be used for the chemical analysis of water samples. Where laboratories of organisations which intend to participate in ECN can demonstrate similar or equivalent well-established protocols and QC/QA procedures, these will be acceptable. However, it is important that participating laboratories report to the CCU the details of intended methods and associated specifications for each determinand.

Author *R. Owen*

Appendix I Physical and chemical variables

Variable	Recording frequency[1] Running waters[2] Recommended	Minimum	Standing waters[2] Recommended	Minimum
Water level	W	M	F	Q
pH[3]	H	M	H	Q
Suspended solids[4]:				
Dry weight	W	M	F	Q
Ash-free dry weight	W	M	F	Q
or Turbidity[3]	H	M	H	Q
or Secchi disk	n/a	n/a	F	Q
Temperature[3,5]	H	M	H	Q
Conductivity[3]	H	M	H	Q
Dissolved oxygen[5]	W	M	F	Q
Ammonium: NH_4–N	W	M	F	Q
Total nitrogen[6]	W	M	F	Q
Nitrate: NO_3–N	W	M	F	Q
Nitrite: NO_2–N	W	M	F	Q
Alkalinity ($CaCO_3$)	W	M	F	Q
Chloride	W	M	F	Q
Total organic carbon[6]	n/a	n/a	F	Q
Particulate organic carbon	n/a	n/a	F	Q
Biological Oxygen Demand	W	M	n/a	n/a
Total phosphorus[6]	W	M	F	Q
Particulate phosphorus	W	M	F	Q
Phosphate (soluble reactive): PO_4–P				
Silicate: SiO_2	W	M	F	Q
Sulphate: SO_4–S	W	M	F	Q
Sodium – dissolved	W	M	F	Q
Sodium – total[6]	W	M	F	Q
Potassium – dissolved	W	M	F	Q
Potassium – total[6]	W	M	F	Q
Calcium – dissolved	W	M	F	Q
Calcium – total[6]	W	M	F	Q
Magnesium – dissolved	W	M	F	Q
Magnesium – total[6]	W	M	F	Q
Aluminium – labile[7]	W	M	F	Q
Aluminium – total[6]	W	M	F	Q
Tin – dissolved	W	M	n/a	n/a
Tin – total[6]	W	M	n/a	n/a
Manganese – dissolved	W	M	F	Q
Manganese – total[6]	W	M	F	Q
Iron – dissolved	W	M	F	Q
Iron – total[6]	W	M	F	Q
Vanadium – dissolved	W	M	n/a	n/a
Vanadium – total[6]	W	M	n/a	n/a

continued...

Variable	Recording frequency[1] Running waters[2] Recommended	Minimum	Standing waters[2] Recommended	Minimum
...continued				
Nickel – dissolved	W	M	n/a	n/a
Nickel – total[6]	W	M	n/a	n/a
Mercury – dissolved	W	M	n/a	n/a
Mercury – total[6]	W	M	n/a	n/a
Copper – dissolved	W	M	n/a	n/a
Copper – total[6]	W	M	n/a	n/a
Zinc – dissolved	W	M	n/a	n/a
Zinc – total[6]	W	M	n/a	n/a
Cadmium – dissolved	W	M	n/a	n/a
Cadmium – total[6]	W	M	n/a	n/a
Lead – dissolved	W	M	F	Q
Lead – total[6]	W	M	F	Q
Arsenic – total[6]	W	M	F	Q

Notes

[1] Recording frequency abbreviations:

H	hourly
W	weekly
F	fortnightly
M	monthly
Q	quarterly
n/a	not applicable

[2] 'Standing water' and 'running water' are used in the text as generic terms to cover more local usage such as broad, lake, loch, lough, and river, brook, beck, burn, stream, respectively. Occasionally, the generic and local terms are used interchangeably

[3] Automatic (continuous) monitoring of pH, temperature, turbidity and conductivity should be implemented where possible. Conductivity should be measured (or compensated for) at 25°C. pH should be measured (or compensated for) at 20°C.

[4] Suspended solids: dry weight should be determined at 105°±5°C and ash-free dry weight should be determined at 500°±20°C.

[5] Standing water profiles: temperature and dissolved oxygen should be monitored at depths appropriate to the standing water site, and the selected depths reported to the ECN Data Manager.

[6] 'Total' implies analysis of the unfiltered sample.

[7] Labile aluminium should only be measured at sites where there is a record of pH ever having been less than 5.5.

FPP Protocol

PHYTOPLANKTON

Aim

To monitor changes in the chlorophyll concentration of standing and running waters and in counts of phytoplankton in standing waters.

Rationale

Many water quality problems in inland waters are related to the growth and accumulation of phytoplankton, the microscopic algae which dominate the pelagic environment. Phytoplankton provides an important source of food for many aquatic organisms and plays a key role in nutrient cycling. The simplest method of estimating the biological productivity of a lake is to measure the concentration of phytoplankton chlorophyll present during the growing season. The conventional method of measuring phytoplankton biomass is to filter a sample of water and then extract the photosynthetic pigment chlorophyll *a*, using organic solvents such as acetone, ethanol or methanol. A detailed discussion of the assumptions and problems of chlorophyll determination is given by Vollenweider (1974) and in papers by Marker (1977) and Marker and Collett (1991). Some water quality problems are, however, caused by qualitative rather than quantitative changes in the phytoplankton so it is also useful to know what species are present at different times of the year. The most important taxonomic groups of phytoplankton are the green algae (Chlorophycae), blue-green algae (Cyanophyceae) and diatoms (Bacillariophyceae – see Protocol FDT, page 81). The identification of phytoplankton to species level is a specialised task but simple guides have been produced by Belcher and Swale (1976) and Pentecost (1984). Quantitative information of this kind is particularly useful in lake studies. The phytoplankton populations in rivers are more difficult to quantify and are strongly influenced by changes in the flow regime.

Method

PHYTOPLANKTON CHLOROPHYLL

(Standing and running waters)

Most investigators in the UK use the hot aqueous methanol method (Talling & Driver 1963) for extracting phytoplankton chlorophyll; cold acetone and cold ethanol methods (Marker 1992; Jespersen & Christoffersen 1987) are used in some laboratories but there is some evidence that incomplete extraction occurs in cold solvent. The hot methanol method appears to be more efficient and is therefore recommended as the standard for ECN at this time. ECN sites must take the necessary steps to ensure that procedures meet statutory health and safety standards (COSHH).

Equipment

Water for both chlorophyll analysis and phytoplankton counts in standing waters should be collected using a suitably designed integrating sampler such as the weighted plastic tube (Lund tube) described by Lund and Talling (1957). A variety of polyethylene containers can be

used for transporting and storing of the phytoplankton sample; they should be easy to clean and large enough to contain 2–3 litres of water. Containers should be washed in recommended detergent (eg Decon®90), rinsed with tap water in the laboratory and subsequently, at each site, with the standing or running water to be sampled.

Location

- **Standing waters**
  Water samples should be taken from a central location near the deepest point and the grid reference should be recorded as accurately as possible, usually to within 30–40 m, together with the water depth at the time of sampling. In circumstances where a boat is not available for sampling it is permissible to sample phytoplankton at the lake outflow or from a jetty or dam which projects over deep water.

- **Running waters**
  The grid reference of locations from which samples are taken at running water sites will be recorded, usually to within 10 m.

Sampling

- **Standing waters**
  Water samples should be collected preferably fortnightly and not less than quarterly. For deep lakes the Lund tube is lowered into the water to the appropriate depth and the weighted end raised by rope to discharge the contained water into the collecting vessel. If the tube is made of relatively stiff material no closing device is required but the sampler may have to be lowered repeatedly to collect a sufficiently large volume of water. For shallow lakes, of depth 1 m or less, and for sites which cannot be sampled by boat, 'bucket samples' are more appropriate. Water samples are collected in a washed plastic bucket that is either carried into the shallows or lowered from a suitable jetty or wall and plunged below the surface to collect a near-surface water sample. Sub-samples of the collected water can be removed by any convenient, objective, volumetric method as long as care is taken to avoid spillage.

- **Running waters**
  Water samples should be collected preferably weekly and not less than monthly. Sampling procedures should follow the guidelines set out in the ECN FSP Protocol (page 49) 'Recommended sampling procedures for water chemistry'. Sub-samples of the collected water can be removed by any convenient, objective, volumetric method as long as care is taken to avoid spillage.

Pigment extraction

The samples of water collected for chlorophyll analysis should be returned to the laboratory as quickly as possible and stored in the dark

at 4°C until they can be processed. In the methanol extraction procedure, a known volume of water is filtered through a glass-fibre (eg Whatman®GF–C) filter and the moist filter paper removed and placed in a test tube. A known volume of 100% methanol is added and the contents of the tube brought to the boil for a few seconds in a water bath or an electrically heated block. The samples are then allowed to stand for 10 minutes at room temperature in the dark before removing the filter papers and centrifuging the extract to remove any particles in suspension. The absorbance of the extract is determined at 665 nm and 750 nm in a 1 cm or 4 cm cuvette as appropriate for the optical density. The absorbance at 750 nm is subtracted from that at 665 nm to correct for general turbidity and background absorption. The chlorophyll *a* concentration in the sample is given by the formula:

$$\text{Chl } a \text{ } \mu g \text{ } L^{-1} = v/V \text{ . } f/l \text{ . } A$$

where v is the total volume of solvent extract in ml, V is the volume of the sample filtered in litres, l is the light path in cm, A is the absorbance at 665 nm corrected for that at 750 nm and f is a factor equivalent to the reciprocal of the specific absorption coefficient multiplied by 10 (estimated as 13.9 by Talling and Driver (1963)).

Method PHYTOPLANKTON COUNTS

(Standing waters only)

Preparation for phytoplankton counting may be done in a variety of ways, including centrifugation and the use of sedimentation chambers. In the recommended method, acidified Lugol's iodine (see Appendix I, page 65) is added to a known volume of water in a graduated cylinder immediately after collection and the sample allowed to stand for 24 hours before siphoning off the supernatant liquid.

Equipment

Water samples should be collected using a suitably designed integrating sampler such as the weighted plastic tube (Lund tube) described by Lund and Talling (1957). A variety of polyethylene containers can be used for removal of the phytoplankton sample. The containers used should be easy to clean and the volume of water used in the graduated cylinders should reflect the presumed productivity of the site, (ie 100 ml for a productive lake and 1000 ml for an unproductive lake). Containers should be washed in recommended detergent (eg Decon®90) and rinsed with tap water in the laboratory and subsequently in lake water at each site.

Location

FPP Protocol

Water samples for phytoplankton counts will normally be taken at the same location and at the same time as those for phytoplankton

chlorophyll determination (see above) (ie they should be collected from a central location near the deepest point). The grid reference of standing water sampling sites should be recorded as accurately as possible, usually to within 30–40 m, together with the water depth at the time of sampling.

Sampling

Water samples for phytoplankton counting should be collected preferably fortnightly and not less than quarterly, using the same methods as are described above for phytoplankton chlorophyll analysis. A note should be made of the presence of significant accumulations of blue-green algae on the water surface at the sampling location.

Counting procedures

A number of cells and chambers have been designed for the microscopic examination of freshwater phytoplankton. One of the most satisfactory methods is that developed by Lund (1959), commonly referred to as the Lund chamber. This simple device is constructed from a rectangular coverslip mounted on thin strips of glass that are then cemented to a glass slide to form a chamber with open ends. A full description of the method of construction is given in Jones (1979), and at least one version is available commercially from the Water Research Centre. The distribution of phytoplankton in a Lund chamber is known to conform to a Poisson distribution (Lund, Kipling & Le Cren 1958) so counting errors are small when compared to the field sampling error. Counts of phytoplankton are made by taxa and related to the volume of the sample; individuals should be identified only to the level of the identifier's expertise. Where sub-sampling is used, its nature must be documented and reported to the CCU. Counts are reported as number of cells per ml by taxon, but where colonial taxa are present they are reported as number of colonies per ml by taxon. Filamentous taxa are reported as length of filament per ml.

Archiving samples

Phytoplankton samples should be archived by preserving a sub-sample of 10–20 ml with a few drops of acidified Lugol's iodine solution in a well-stoppered container. Note that if plastic containers or stoppers are used the iodine will eventually volatilise. However by that time the iodine should have successfully sterilised the sample and should not therefore cause a problem. Archived samples should be checked periodically for evaporative loss.

Author *D. G. George*

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Appendix I

Lugol's iodine is prepared as follows (Wetzel & Likens 1991).

Acidified

Dissolve 20 g potassium iodide and 10 g iodine crystals (caution: toxic) in 200 ml distilled water containing 20 ml concentrated glacial acetic acid.

Non-acidified

Dissolve 20 g potassium iodide and 10 g iodine crystals in 200 ml distilled water.

To preserve samples with Lugol's iodine add 0.3 ml of the solution to 100 ml of sample and store in the dark. For long-term storage add 0.7 ml of the solution per 100 ml of sample and buffered formaldehyde to a minimum of 2.5% final concentration after 1 hour.

FMA Protocol

AQUATIC MACROPHYTES

Aim

To monitor change in the aquatic macrophytes of rivers and lakes.

Rationale

Macrophytes are an important component of the aquatic ecosystem and broad changes in the abundance of individual species and community composition provide valuable information on how and why an ecosystem might be changing. Macrophytes are also becoming increasingly valued as a means of indirectly monitoring water quality as, for instance, eutrophication can produce a progressive change in species composition and a loss of species diversity.

Since the emphasis of the freshwater monitoring programme is on the aquatic environment, the macrophyte survey covers plants growing in the water body but not the adjacent banksides. "Bank species" occurring above the level of the river or lake are not recorded because the influence of the river or lake substrate and water chemistry are likely to be less important than local edaphic and climatic influences. The river channel (and by analogy, the lake) is defined in accordance with Holmes (1983): "The 'River' is defined as those parts of the substrata which are likely to be submerged for 85% of the time, whilst 'Bank' is that part of the side of the river (or islands) which is submerged for more than 50% but less than 85% of the time."

Macrophytes include any plant observable by the naked eye and nearly always identifiable when observed (Holmes & Whitton 1977). This includes all aquatic vascular plants and bryophytes, together with groups of algae which can be seen to be composed predominantly of a single species.

It will, however, rarely be possible to survey whole rivers and lakes and in most cases macrophyte surveys will be undertaken at selected sampling points. The main requirement is that the methods employed should be consistent so that information can be used to compare change both within and between sampling points at different sites and times. Common procedures have been recommended for lakes and rivers wherever possible.

This protocol aims to provide data on the following:

i. Species present and their relative abundance. Although some groups, eg charophytes, are often identified only to family level it is recommended that all macrophytes are identified to species level. Details of the check list of aquatic macrophytes used in ECN are provided in Chapter 3 of this volume (page 106).
ii. Species distribution along a river length and, in lakes, zonation at selected sample points.
iii. Physical characteristics of the sampling location.

Wherever possible the recommended methods are close adaptations of existing, widely practised methods in order to ensure continuity with historic data and to reduce the need for training. Although a number of techniques have been developed for survey and monitoring of aquatic macrophytes in rivers (eg Patrick *et al.* 1991; Environment Agency 1996) and lakes (Wolfe-Murphy *et al.* 1991), and for characterising waterside habitats (Boon *et al.* 1997), none of these alone meets the requirements of ECN, particularly in relation to its need for detailed data for detecting change at individual sites. This protocol takes into account the rationale and methods adopted in vegetation monitoring at ECN's terrestrial sites (Rodwell *et al.* 1996) which is based on recording presence and absence of species in a large number of small quadrats. Some elements of this approach have been used in the methods described below but the use of fixed, small quadrats for recording presence and absence is a less practical and familiar technique in aquatic macrophyte surveys; thus the more common approach of estimating cover in larger areas has also been used.

Method

STANDING WATERS

Since in most cases it is impossible to sample thoroughly a whole lake, a transect approach will be used to monitor specific locations which are generally representative of the whole lake. In addition, depending on the availability of resources, site operators are encouraged to carry out a more general, qualitative survey, in order to establish a species list for the whole lake. However, the methodology for such an additional survey should be determined by the site operator and is not included within this protocol.

The main steps in the survey procedure are:

i. general site survey and mapping of lake margin zones to identify representative sampling locations;
ii. selection of sampling points in the representative locations around the lake;
iii. shoreline surveys around the edge of the lake, centred on the sampling points;
iv. deep water transects across the littoral zone, starting from the same sampling points.

Data gathered from the surveys will provide information on the presence/absence of species along sections of shoreline and along gradients of increasing water depth. The point on the shoreline chosen as the starting point of each transect survey will be referred to as a sampling point. Decisions on the location and number of sampling points should be made following an initial appraisal of the lake as described below.

Equipment

- Wading boots.
- Metre rule calibrated in 0.01 m intervals.
- Boat large enough for two/three people plus equipment (see Health & Safety, page 78).
- Ekman grab on rope calibrated in 0.1 m intervals.
- Bathyscope (see Appendix I, page 80) or camera.
- Hand-held echo sounder (optional – see Appendix I, page 80)
- Plastic bags.
- Waterproof note book or paper with entry table prepared.
- Bucket.
- Floating transect rope mounted on rope winder (eg a monkey ladder). The rope should be calibrated in 2.5 m intervals to 10 m, then every 5 m. Allow approximately 5 m of "free" rope before the first calibration mark for attachment to the shore.
- Anchor rope attached to heavy anchor (eg a large boulder).
- Marker buoy (the size of a football or larger).

Location

The number of sampling points will depend on the resources available and on the heterogeneity of the vegetation. Macrophyte surveys at each sampling point are likely to take approximately three to four hours. Wherever possible, sampling points should be located within examples of each of the main vegetation types characteristic of the lake.

An initial appraisal of the whole lake should be made to ascertain which locations within it are most suitable for transect surveys. This is achieved by carrying out a general site survey supplemented, where possible, by advice from aquatic macrophyte experts familiar with the lake, or by reference to existing habitat/vegetation maps. The shoreline is traversed either by wading or by boat, employing a combination of grapnel and grab techniques to identify the major stands of emergent, floating-leafed and submerged macrophytes which are then mapped on a plan of the shore outline. The aim at this stage is not to identify all plants to species level, but to obtain a generalised view of macrophyte cover and zonation. A plumbline or hand-held echo sounder should be used to assess the degree of offshore slope in locations of potential sample points.

The following guidelines should be followed when selecting sampling points.

i. Locations close to inflows or potential pollution point sources, which are likely to exert significant local influence on the lake, are to be avoided.

ii. Each sampling point should be situated in a location where macrophyte cover and species richness are representative of one of the main macrophyte communities of the lake littoral zone,

both along the shoreline and along the deep water gradient. These locations will usually be situated in more sheltered parts of the lake where disturbance by wave action and wind is minimal.

iii. Ideally, the lake basin morphometry adjacent to the survey point should be simple and contours of lake depth should be approximately parallel to the lake shoreline.

iv. Ideally, aquatic macrophyte species should show some zonation with increasing depth, and should show relative homogeneity along any depth contour, for at least 20 m on either side of the intended deep water transect line.

v. Ideally, sites should be located where the deep water transect slope is gradual, so that the maximum depth at which macrophytes occur lies at least 30 m offshore. If there are no suitable locations where the macrophyte zone extends more than 5 m from the lake shore, due to extreme slope or very poor water transparency, only shoreline transects are needed. If it is possible only to identify sites in which the macrophyte zone lies 5–30 m offshore it may be necessary to decrease the deep water transect sampling interval, (eg from 5 m to 2.5 m).

Each sampling point should be marked in such a way as to enable its precise relocation on future visits. A unique code and NGR for each point should be recorded. The shoreline survey will always cover the same area 50 m on either side of the sampling point. However, due to the destructive nature of sampling, the origin of the deep water transect should be varied between visits by up to 5 m along the shoreline on either side of the sampling point.

Shoreline survey

- **Location**

  At lakes where there is evidence of variability in water level, the high water mark should be used as the upper limit of the shoreline. Lakes which show regular and large fluctuations (>0.3 m) in water level are unsuitable for the application of this protocol. The shoreline survey should be undertaken on foot by a surveyor wearing wading boots. The distance from the shore may be limited by the maximum depth (D_{max}) in which wading is considered safe and practicable. The value of D_{max} should be fixed for a particular lake and used on all future surveys.

  The survey should cover an area with a shoreline length of 100 m, centred on the sampling point, and a width (W) of either 5 m or the distance at which the depth equals D_{max}, which ever is less. A record should be made of i) width (W) and ii) sampling depth (D) at distance (W) from the shore, where either:

  i. width = 5 m, maximum sampling depth $\leq D_{max}$; record width (W) as 5 m and sampling depth (D) ±0.1 m), or;

ii. width <5 m; record actual width (W) ±0.5 m and maximum sampling depth (D_{max}).

These variables will be recorded on all future surveys at the sampling site.

The 100 m length should be divided into ten sections of 10 m using canes (non-permanent) to mark the shoreline limits of each section. The width limit can be marked temporarily using one or more marker buoys to provide the surveyor with reference points.

Sampling

Surveys should be repeated every two years from the same sampling points. Ideally all surveys should be undertaken in July/August but the date of the first survey should determine the date of subsequent surveys.

The lake level should be recorded against a standard benchmark at the time of sampling.

Starting at the section to the far left looking towards the lake (Section #1) the surveyor should walk the section, using a bathyscope if this is necessary to detect submerged species, and record the presence of all emergent, floating and submerged macrophytes on a standard form. For each sampling point the data collected will therefore comprise a species list for each section numbered 1–10. Where it is impossible to wade, the surveyor may walk along the shore or use a boat (with appropriate safety procedures), using a grapnel to retrieve plants for identification. A record should be made of the technique adopted.

In the event of a species being detected which cannot be identified by the surveyor, a sample should be taken (providing this is unlikely to affect the lake population of the species) and sealed in a labelled polythene bag for subsequent identification.

A sketch map should be made of the 100 m length of shoreline showing in the broadest terms the general physical character of the surveyed section in relation to prominent physical features of the site. The purpose of the map is to enable future relocation of the survey and to provide an annotated record of specific features related to the site, which may assist in the interpretation of the quantitative data. It is not necessary to make a detailed map on each survey occasion.

Main features to be marked on the sketch map are:

- NGR for both ends of the surveyed 100 m length;
- Grid north;

- relocation features, (eg distances to bridges, trees, boulders);
- points from which photographs are taken;
- shading position and type – broken shade (using stippled shading pattern) or dense (solid shading);
- main macrophyte stands (shown with cross-hatched shading);
- adjacent land use (eg arable, pasture, forest, factory, houses/gardens).

On each survey occasion the general physical character of the site is recorded. The following attributes should be recorded in each 10 m section as an aid in the interpretation of macrophyte data (see Chapter 3, pages 103–107, for details of attributes and their categories):

i. *Substrata*: Estimates should be based on a birds-eye view and should include only surface particles which are directly visible or hidden under macrophytes. If shapes of underlying larger particles are distinct under a layer of fine particles such as silt or clay then the larger particles should be recorded. Record the percentage cover of each substrate category in the appropriate box on the recording sheet.

ii. *Shading*: Record the percentage of the shoreline section shaded (not the length of bank affected), in each shading category, when the sun is overhead (ie at 12 noon).

Photographs should be taken of the main emergent and floating-leafed macrophyte beds covered by the survey. The use of a polarising filter to reduce surface reflection is recommended. The location of the point (±2 m) from which each photograph is taken and the direction of the shot should be recorded on the sketch map. Points should be referenced by means of an obvious and permanent land feature, or by the use of global positioning satellite instrumentation. Copies of all photographs should be labelled with site, date and location within site and sent to the CCU for long-term storage. The photographs should also be annotated to highlight any key features.

Deep water survey

- **Location**
  It is recommended that three people are used to locate a deep water transect, though two people may be sufficient if a boat with a small outboard engine is used. The following guidelines are recommended.

  i. Secure the free end of the floating transect rope on the shoreline within 5 m of the sampling point, attaching it either to a stake or to available supports such as a fence post or large boulder. The precise location should be varied between visits.

ii. Manoeuvre the boat on a course approximately perpendicular to the lake shore, releasing the transect rope under light tension. If an outboard engine is used the boat can be reversed from the shore so that the rope is paid out from the bow. It may be helpful to position a pair of surveyor's ranging poles about 10 m apart and behind the shore along the intended line of the transect to provide a sight line.

iii. Once the full length of the transect rope has been released it should be tightened by continuing to head the boat outwards, and if necessary the angle from the shore should be adjusted. With the transect rope under tension, the anchor should be lowered, and the anchor rope tied off at the water surface to a buoy and then fastened to the transect rope.

iv. The last 5 m section of the transect should extend just beyond the limit of macrophyte growth.

Sampling

The survey should be repeated every two years. Ideally all surveys should be undertaken in July/August but the date of the first survey should determine the date of subsequent surveys.

A compass bearing on the position of the deep water transect buoy should be taken from the sampling point; this bearing will be used to help relocate the direction of the transect in future years.

Samples will be taken at 5 m intervals from the shore; each 5 m mark on the transect rope will be referred to as a transect point (see Figure 3, page 80). Starting from the shoreline end, the boat should be moved to the first transect point. The boat should be attached to the transect rope at the bow and stern. At each transect point separate port and starboard measurements are taken using at least one but preferably all three of the following techniques. Selection of the appropriate techniques will depend on the nature of the macrophyte community structure, (eg an Ekmann grab may be sufficient in oligotrophic lakes dominated by isoetids). Advice on the choice of techniques can be obtained from the CCU. Although the data from up to three techniques will be combined eventually within the data base to produce species lists for the port and starboard locations, data from each measurement should be recorded separately as an aid to interpretation.

i. An Ekman grab sample is taken with its rope held immediately adjacent to the side of the boat. All species retrieved are recorded.

ii. While the Ekman grab is still in place, record all species present in a 1 m^2 circular plot (radius = 560 mm) around the grab using a bathyscope or underwater camera to scan the area. A standard Ekman grab has a width of 140 mm and the plot radius is therefore equivalent to four Ekman grab widths: it may be helpful, therefore, to use this to judge whether macrophytes fall within the prescribed area. All species within this area which are identifiable to species level remotely (ie without being retrieved) are recorded. Utmost care must be taken to avoid mis-identification. If there is in any doubt over the identification of a plant, it should not be included within the final species list for the transect point.

iii. Allowing enough slack rope to permit free-fall to the lake bed, a macrophyte grapnel (eg double-headed rake) is lobbed into the water approximately 2 m out from the side of the boat in a direction perpendicular to the transect line. Having allowed time for the grapnel to reach the bottom, it is then retrieved at a rate slow enough for it to drag over the lake bed until its rope is approximately vertical, before hauling it to the surface. All species retrieved are recorded.

The following additional data should be collected for the port and starboard locations at each transect point.

i. *Sample depth*: Measured using the calibrated Ekman grab rope or, with more accuracy, with a hand held echo sounder.

ii. *Substrate*: The predominant substrate type using the categories listed in Chapter 3, pages 105–106.

iv. *Total plant cover*: A visual estimate of the percentage cover of live vegetation within the area described in paragraph 2 above, to the nearest 10%. Any cover deemed to be less than 5% should be recorded as a +.

The following should be recorded for each transect.

i. *Maximum depth of vascular plant growth*: The maximum depth at which vascular aquatic macrophyte species will grow is often controlled by water transparency. It is usually possible to observe their depth limit from the lake surface if a suitable underwater viewing device such as a bathyscope is employed.

ii. *Secchi disc depth*: A reading should be taken at the deepest point of the transect or, if at this point the disc is visible on the bed of the lake, in deeper water.

iii. *Limit of macrophyte growth*: The limit of macrophyte growth should be recorded, (ie the distance along the transect from the shore, ±0.5 m).

A sketch of the deep water transect profile should be made incorporating information gathered from the Ekman grab samples, grapnel hauls and from visual observations made using the bathyscope.

Photographs should be taken of the main emergent and floating-leafed macrophyte beds covered by the survey. The use of a polarising filter to reduce surface reflection is recommended. The location of the point (±2 m) from which each photograph is taken and the direction of the shot should be recorded on the sketch map. Points should be referenced by means of an obvious and permanent land feature, or by the use of global positioning satellite instrumentation. Copies of all photographs should be labelled with site, date and location within site and sent to the CCU for long-term storage. The photographs should also be annotated to highlight any key features.

Method RUNNING WATERS

Equipment

- Wading boots.
- Metre rule calibrated in 0.01 m intervals.
- Bathyscope (see Appendix I, page 80) or camera.
- Plastic bags.
- Waterproof note book or paper with entry table prepared.
- Grapnel with depth markings on rope.
- Tape measure, stakes, canes or other marking devices to mark section lengths.
- Optical range finder (optional).
- Boat, large enough for two people and equipment (see Health & Safety, page 78).
  Life jackets, dry suit.

Location

The macrophyte survey should cover a 100 m length of the river immediately upstream of the ECN chemical sample point (see FSP protocol, page 49). If this is not practical, the nearest suitable 100 m length upstream of the sample point should be used. The downstream and upstream limits should be defined by reference to suitable landmarks and Grid References and should be permanently marked and precisely relocatable (±0.5 m).

The 100 m length should be divided into ten sections of 10 m using stakes or canes, or any other suitable method, to mark the end points of each section.

Sampling

The technique is based on "Methodology for the Assessment of Freshwater Riverine Macrophytes for the purposes of the Urban Waste Water Treatment Directive" (UWWTD) (Environment Agency 1996) which is itself based on the "Blue Book Method B" (Standing Committee of Analysts 1987). It is designed to exploit the value of macrophytes as a water quality monitoring tool and aims to observe, identify and record, over a standard survey river length (usually 100 m), the macrophyte species present in the river channel, and to provide a semi-quantitative estimate of the overall percentage cover of plants.

This approach has been adopted for ECN sites so that results can be directly compared with other surveys using the same technique. Additionally, in order to provide more detailed data on macrophyte distribution as an aid in the detection of long-term change, each site is divided into smaller sections in which measurements of the cover of each species present are made.

Sampling should be undertaken annually at the same location in July or August, ideally when the river has been at a normal low flow for several days and when it is not discoloured. A survey carried out when a river is in flood or is highly discoloured is unlikely to provide useful information. Timing of weed cuts should also be taken into account since they frequently occur between June and September. Once the timing of a survey has been fixed, subsequent surveys should be undertaken at the same time each year, being changed only when necessary to avoid the effects of weed cuts, high flows or discolouration.

All species of floating and submerged macrophytes should be recorded. The survey method covers those 'river macrophytes' contained within the river channel area. All such macrophytes seen submerged or partly submerged at low flow levels are recorded. At the sides of the river all macrophytes growing on parts of the substrata which are likely to be submerged for more than 85% of the time are also included. As it is best to survey macrophytes when the river has been in low flow for several days this is fairly easy to interpret consistently. 'Bank species' and macrophytes overhanging the river channel but not rooted in the channel should not be recorded.

Percentage cover of all species in the river channel should be estimated for each species in each 10 m section of the 100 m length. As an aid to estimating percentage cover of individual species it is useful, before starting the survey, to calculate what a 1 m^2 patch of macrophyte represents for each 10 m section, (eg it may be 0.1% or 0.5%).

In the event of a species being detected which cannot be identified by the surveyor, a sample should be taken (providing this is unlikely

to affect the population of the species), sealed in a labelled polythene bag and retained for subsequent identification.

Different techniques are required, depending on whether a site is sufficiently shallow to be waded in safety.

i. At sites where it is safe for the surveyor to enter the watercourse, the survey can be carried out by wading. At most sites this will mean that a second person will be required for safety reasons. Wading should be done in an upstream direction. Where some (<20%) of the length cannot be waded then it is acceptable to walk for a short distance along both banks, using a grapnel to retrieve submerged macrophytes for identification. The surveyor should wade in a zig-zag manner across the channel, investigating all types of habitat present. All species present in each 10 m section are recorded. The operator should cross the channel at least twice in each 10 m section.

ii. At sites where the channel is narrow (<5 m) and it is not possible to use a boat, if the macrophytes can be seen clearly it is sufficient to walk along both banks and use a grapnel to retrieve material for identification. At other sites, where flow is slow, a small boat should be used, provided that recognised safety guidelines are followed. Each 10 m section is traversed and species presence recorded in the same way as for wadeable rivers. An underwater TV camera or a bathyscope must be used to observe any macrophytes which cannot be seen clearly from the surface. A grapnel should be used to retrieve submerged plants for identification.

On each survey occasion the general physical character of the site is recorded. The following attributes should be recorded in each 10 m section as an aid in the interpretation of macrophyte data (see Chapter 3, pages 103–107, for details of the attributes and their categories):

i. *Width:* This is the average width of the channel across which macrophytes have been recorded. Usually it will be sufficient to measure the width of the channel at the mid-point of each 10 m section using tape measures or ropes with 0.5 m divisions, or an optical range-finder. If the channel width varies irregularly, then the average of three measurements made at the centre and two ends of the section should be used.

ii. *Depth:* Measure the depth at various points in the section; the number and exact location of the measurement points should depend on the variability of depths encountered when surveying the macrophytes. Record the depth by entering the percentages in each depth category.

FMA Protocol

iii. *Substrate:* Estimates should be based on a birds-eye view and should only include surface particles which are directly visible or

hidden under macrophytes. If shapes of underlying larger particles are distinctly visible under a layer of fine particles such as silt or clay then the larger particles should be recorded. Record the percentage of the section in each substrate category.

iv. *Habitats:* Record the percentage of the section in each habitat category.

v. *Shading:* Record the percentage of the section in each shading category when the sun is overhead (ie at 12 noon) by summing estimates made from both banks to the centre of the channel.

vi. *Water clarity:* Estimate the percentage of the section in each category. This is necessary because a survey length may be clear in the shallow margins and progress through cloudy to turbid as the water depth increases.

vii. *Bed stability*: Record the percentage of the section in eac category.

A sketch map should be made of the 100 m length showing, in the broadest terms, the general physical character of the site. The purpose of the map is to enable future relocation of the survey and to provide an annotated record of specific features related to the site which may assist in the interpretation of the quantitative data. It is not necessary to make a detailed map on each survey occasion. The map should be drawn so that the direction of flow is from the bottom to the top of the paper.

Main features to be marked on the sketch map are:

- NGR for both ends of the surveyed 100 m length;
- Grid north;
- width of the channel (as included in the survey);
- relocation features (eg distances to bridges, trees, boulders);
- points from which photographs are taken;
- shading position and type – broken shade (using stippled shading pattern) or dense (solid shading);
- main macrophyte stands (shown with cross-hatched shading);
- extent of riverbanks – riverbank is defined as the area before an adjacent land use starts;
- adjacent land use (eg arable, pasture, forest, factory, houses/ gardens);
- direction of flow.

More extensive habitat mapping for the site may be completed as part of the River Habitat Survey (RHS) (Environment Agency 1997, Raven *et al.* 1997). The RHS is an optional protocol for ECN freshwater sites; it covers a 500 m stretch and should be chosen to include the 100 m length used for the macrophyte survey.

Photographs should be taken of the main emergent and floating-leafed macrophyte beds covered by the survey. The use of a

polarising filter to reduce surface reflection is recommended. The location of the point (±2 m) from which each photograph is taken and the direction of the shot should be recorded on the sketch map. Points should be referenced by means of an obvious and permanent land feature, or by the use of global positioning satellite instrumentation. Copies of all photographs should be labelled with site, date and location within site and sent to the CCU for long-term storage. The photographs should also be annotated to highlight any key features.

QUALITY ASSURANCE IN MACROPHYTE SURVEYS

Quality assurance is an important part of the recording process, particularly where species exhibit a plastic morphology and/or where hybrids frequently form (eg *Potamogeton* species and Charophytes).

It should be achieved by ensuring the following:

i. Collection and preservation of voucher specimens and the exchange of specimens with botanical experts, such as those based at the Natural History Museum and the Biological Records Centre (BRC) at ITE Monks Wood. Plants are best kept by preserving between newspaper sheets or blotting paper, or by preserving in formalin or alcohol. The latter is preferred, particularly for fine-leafed small species since macrophytes become brittle when dried out. Soak the plants in 5% formalin overnight then transfer them to well labelled air-tight polythene bags.

ii. Use of trained surveyors.

iii. Use of aerial photographs of an appropriate scale as a means of clarifying the extent of the main macrophyte stands of the river or lake.

HEALTH AND SAFETY

Field workers should follow their employer's regulations regarding health and safety, risk assessments and COSHH (Control of Substances Hazardous to Health). General guidance on health and safety precautions are given in National Rivers Authority (1996); this covers precautions associated with:

i. chemical hazards associated with collection and laboratory identification;
ii. physical hazards in the river and water channel;
iii. clothing and equipment;
iv. working procedures;
v. use of boats.

Authors *T. W. Parr, D. T. Monteith & M. Gibson*

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Appendix I

Suppliers

Details of suppliers of hand-held echo sounder, bathyscope, and Ekman Grab are obtainable from the CCU.

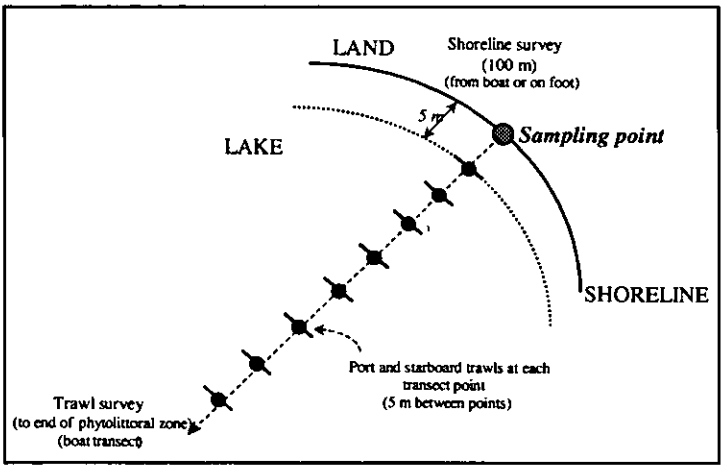

Figure 3. Relationship between transect point and the shoreline and trawl surveys

FDT Protocol

EPILITHIC DIATOMS

(Standing and running waters)

Aim

To monitor changes in the species composition of epilithic diatom communities in standing and running waters.

Rationale

Diatoms are a diverse group of unicellular siliceous algae and are well-established as sensitive biological indicators of surface water quality due to the narrow tolerance of individual species to environmental parameters such as pH and nutrient availability (Round 1993). Diatom epilithon grow attached to submerged stones within the photic zones of lakes and streams and are easy to sample in most freshwaters in a replicable manner. The sampling procedure adopted by ECN is simple and follows that used for the United Kingdom Acid Waters Monitoring Network (Patrick *et al.* 1995).

For the purposes of ECN, epilithic diatom samples will be sent to the Environmental Change Research Centre (ECRC) laboratories (see Appendix I, page 85), where they will be prepared by hydrogen peroxide digestion and mounted on microscope slides (see Battarbee 1986). The slides will be archived in anticipation of the availability of funding for analysis at some time in the future. Analysis will involve examination by x 1000 microscopy, with 500 diatom valves from each sample being identified to species level. Data will be summarised for each sample as a list of species present and their percentage abundance.

Method

Equipment

A toothbrush, small plastic funnel, sample tray, 30 ml screw-top Sterilin® polystyrene vials, acidified or non-acidified Lugol's iodine, distilled or filtered water in a wash bottle, penknife.

Location

- **Standing waters**
  Three spatially discrete littoral locations, which are not unduly influenced by inflow streams or localised catchment disturbance, heavy shade etc, are selected around the shore. The locations are recorded on a sketch map to assist in future re-location and grid references of each sampling location are recorded, usually to a resolution of 30–40 m. Sampling is carried out preferably three times each year, in March–April, June–July and September–October. Once a sampling schedule has been determined, sampling dates should be adhered to as closely as possible in future years. If only annual sampling is possible, this should be carried out during September.

Running waters

A 50 m length of stream is selected to coincide with part of that used for ECN macrophyte sampling. Three sampling locations, which are not unduly influenced by inflow streams, localised catchment disturbance, heavy shade, etc, are selected along this length – the first near the upstream end (Location 1), the second at its centre (Location 2), and the third near its downstream end (Location 3). Grid references of each sampling location are recorded to a resolution of 10 m (or better if possible). Sampling is carried out preferably three times each year, in March–April, June–July and September–October. Once a sampling schedule has been determined, sampling dates should be adhered to as closely as possible in future years. If only annual sampling is possible, this should be carried out during September.

Sampling

Standing waters

At each location five permanently submerged cobble-sized stones, ideally from a depth >30 cm, are selected and epilithic diatoms removed and preserved. For this purpose a cobble is defined as a large stone which can be held in one hand; if this size of stone is unavailable, smaller or larger stones may be substituted and a record made so that a similar size is used on each subsequent sampling occasion. Stones covered in bryophytes or macro-algae, (eg *Cladophora*), should be avoided. Epilithic diatoms, usually discernible as a brownish slimy cover on the upper surface of submerged stones, are removed from the stones into a tray by vigorous brushing with a clean toothbrush. Alternatively, the blade of a penknife may be used to scrape the stones. The stones should be rinsed 2–3 times with a few drops of distilled or filtered water and re-brushed. The bulk sample for each sampling location (ie from the 5 stones) is homogenised in the tray, (eg by stirring with the toothbrush), and a subsample is then decanted to fill a plastic vial and preserved with 2–3 drops of Lugol's iodine (see Appendix II, page 85). The remaining solution may be discarded. Each tube is labelled as described below.

The toothbrush should be thoroughly cleaned between sampling different sites.

Running waters

At each of the three sampling locations five cobble-sized stones are selected and removed from the water, preferably from stretches of at least moderate flow and at a depth below that of minimum flow. For this purpose a cobble is defined as a large stone which can be held in one hand; if this size of stone is unavailable, smaller or larger stones may be

substituted and a record made so that a similar size is used on each subsequent sampling occasion. Stones covered in bryophytes or macro-algae, (eg *Cladophora)*, should be avoided. Epilithic diatoms, usually discernible as a brownish slimy cover on the upper surface of submerged stones, are removed from the stones into a tray by vigorous brushing with a clean toothbrush. Alternatively, the blade of a penknife may be used to scrape the stones. The stones should be rinsed 2–3 times with a few drops of distilled or filtered water and re-brushed. The bulk sample for each sampling location (ie from the 5 stones) is homogenised in the tray, (eg by stirring with the toothbrush), and a subsample is then decanted to fill a plastic vial and preserved with 2–3 drops of Lugol's iodine (see Appendix II, page 85). The remaining solution may be discarded. Each tube is labelled as described below.

The toothbrush should be thoroughly cleaned between sampling different sites.

Unavailability of epilithic habitats

At sites where a suitable habitat for epilithon is unavailable, such as lowland nutrient-rich lakes with thick reed fringes or streams with silty or clay/mud beds, an epiphytic diatom sample is substituted as follows.

At each of the three sampling sites, remove three small pieces of permanently submerged macrophyte material using a penknife, place in a plastic vial with a little distilled or filtered water, and preserve with several drops of Lugol's iodine. The stems of reeds and rushes and the undersides of lilies and broadleafed species provide particularly favourable habitats for epiphytic diatoms but they should be checked to ensure that they have the brownish, slimy cover indicative of diatom communities before they are selected. The macrophyte species should be sufficiently abundant at the sample location to facilitate sampling of the same species in the future, and a brief description of the selected macrophyte should be added to the vial label.

Labelling

Each tube is identified uniquely by:

- the ECN Measurement Code (FDT)
- the ECN Site ID Code (eg Lochnagar L09)
- the internal location code* (eg S01 – see below)
- the collection date (eg 10-Mar-95)

* The internal location code identifies the particular sampling point within the ECN Site, and takes the form: Xnn

where 'X' is either S = Stone substrate (epilithic) or P = Plant substrate (epiphytic) and 'nn' is a numeric code: 01, 02 03, etc. For running waters, 01 is used for upstream location, 02 for centre location and 03 for downstream location of the ECN stream section. For standing water sites, codes are assigned as seems most appropriate.

Where the sample is epiphytic, information about the selected macrophyte should be included.

Samples should be stored in the dark in a cool environment and, if necessary, sent as soon as possible to a ECRC (see Appendix 1, page 85) adequately sealed, protected with padding and accompanied by any appropriate field notes. Grid references of each sampling location should also accompany the first batch of samples.

Author

D. T. Monteith

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Appendix I

Environmental Change Research Centre
University College London
26 Bedford Way
London WC1H 0AP

Appendix II

Lugol's iodine is prepared as follows (Wetzel & Likens 1991).

Acidified

Dissolve 20 g potassium iodide and 10 g iodine crystals (caution: toxic) in 200 ml distilled water containing 20 ml concentrated glacial acetic acid.

Non-acidified

Dissolve 20 g potassium iodide and 10 g iodine crystals in 200 ml distilled water.

To preserve samples with Lugol's iodine add 0.3 ml of the solution to 100 ml of sample and store in the dark. For long-term storage add 0.7 ml of the solution per 100 ml of sample and buffered formaldehyde to a minimum of 2.5% final concentration after 1 hour.

CRUSTACEAN ZOOPLANKTON

Aim

To monitor changes in the abundance of crustacean zooplankton in standing waters.

Rationale

The crustacean zooplankton which dominate the open water of lakes form an important link in the food chain between phytoplankton and fish. Most lakes contain a few species from a small number of genera but marked changes in species composition can occur when there is a progressive change in the trophic status. The distribution and occurrence of freshwater zooplankton populations are notoriously patchy. Different species tend to concentrate at different depths and there are often local accumulations produced by wind-induced water movements (George 1981). Detailed population studies require very intensive sampling but a single integrated sample collected from a central location can produce useful results for more general surveys of seasonal and inter-annual change.

Method

Equipment

Samples are collected with a net fitted with a non-porous reducing cone to increase the efficiency of filtration and designed according to the principles outlined in Tranter and Smith (1968). The area of gauze used in the net must be large enough to filter the water efficiently and the porosity of the gauze chosen to minimise the risk of clogging. The type of mesh used for the construction of a net has a marked effect on the efficiency and selectivity of the net. Nets made from stainless steel mesh are robust, easy to clean and have more precise mesh dimensions, but nets made from nylon are more readily obtainable from commercial suppliers; nets with a diameter of 25 cm will normally be used. Nets with a mesh size of 140–150 µm, which deliberately exclude rotifers, are recommended (see Appendix I, page 89). The area and mesh size of nets used at any site must in any case be standardised and reported to the CCU.

Small glass, polyethylene or polycarbonate containers can be used to store zooplankton samples. The containers selected should be reasonably robust and fitted with lids or closures which minimise the quantity of liquid lost by evaporation during prolonged storage.

Location

Samples should be collected preferably fortnightly, but not less than quarterly, at a central location near the deepest point in the lake. In circumstances where a boat is not available for sampling it is permissible to sample zooplankton at the lake outflow or from a jetty or dam which projects over deep water.

The grid reference of the sampling site should be recorded as accurately as possible, usually to within 30–40 m, together with the water depth at the time of sampling.

Sampling

Samples are collected by hauling a net, at a steady speed, from the bottom to the surface of the standing water. Where water depth exceeds 100 m the net should be hauled from a depth of 100 m to the surface. Care should be taken to wash any animals adhering to the side of the net into the collecting vessel. The net should be washed in lake water after use and then dried to minimise the risk of transferring organisms between sites. Samples should be killed in the field by adding a few drops of 40% formaldehyde to the sample in its storage container. If too much formaldehyde is added in the field, any Cladocera in the sample will shed a high proportion of their eggs which may then be lost during subsequent laboratory processing.

In-house procedures for using formaldehyde are provided by the Environment Agency (1997). These procedures have been tested to meet statutory safety standards (COSHH); however, every laboratory using these procedures, or other procedures authorised by their own laboratory, must carry out its own safety assessment, tailored to its own particular conditions and facilities. 100 ml of undiluted formalin (40% aqueous formaldehyde) should be placed in a 150 ml Nalgene screw-topped bottle in the laboratory, using a fume cupboard or fume extractor. A bottle of fixative should be placed in each sample container. In the field a few drops of the formalin should be added to the sample. The cap is then replaced on the bottle containing the unused formalin this is itself replaced in the sample container. This procedure must take place outside, in a well-ventilated area and **not** inside a vehicle. Adherence to this procedure ensures that the formalin is always double-sealed, prevents large volumes of fixative being carried in the same container and limits the total volume being carried to that required for sampling. Protective gloves must always be worn when handling concentrated formalin.

Samples may be stored either in formaldehyde or in alcohol. If the samples are to be stored in formaldehyde, enough 40% formaldehyde should be added on returning to the laboratory to give a final concentration of 4–5%. If the samples are to be preserved in alcohol, the animals should be removed by filtering through a suitable mesh and then re-suspended in 70% alcohol. When using either formaldehyde or alcohol, precautions must be taken to minimise skin contact and avoid exposing operators to vapour. Samples should be washed with water before sorting and re-suspended in preservative as soon as they have been examined microscopically.

Counting procedures

Several types of counting chamber have been designed for examining zooplankton in the laboratory. The simplest are machined from a rectangular block of 'Perspex' but the most convenient are those designed to rotate on the stage of a stereo-zoom microscope. Jones

(1979) describes and illustrates the type of circular 'Perspex' moat used at the IFE, Windermere, for zooplankton counting. The sample is dispensed into a machined 'moat' fitted with a radial barrier and the chamber is rotated on its central spindle until all the animals have been counted. If a sub-sampling procedure is used to prepare material for counting, its nature must be reported to the CCU. Counts are reported as number of individuals per litre by species.

Estimation of biomass

An estimate of zooplankton biomass is a useful additional measure. Acceptable estimates of the seasonal and inter-annual changes in biomass can be obtained using simple volumetric techniques. George and White (1985) compared a rapid method of estimating the settled volume of preserved plankton with a more complex displacement volume method (Tranter 1959). The results demonstrated that reliable settled volume estimates can be obtained for most species of freshwater zooplankton, but the glass tubes used for such measurements should be carefully matched to the expected volume of sample. Samples are normally stored in flat-bottomed glass tubes with an internal diameter of 1.8 cm and the height of the settled material is measured with a transparent ruler.

Settled volume is reported as millilitres (ml).

Archiving samples

Zooplankton samples should be archived by storing in 4% formaldehyde containing a small quantity (2–3%) of glycerol to protect the samples from evaporation. Samples should be checked periodically for evaporative loss.

Author

D. G. George

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Appendix I Equipment details

Nets of a suitable quality and specification are obtainable from various biological equipment suppliers for approximately £50. Details of suppliers can be obtained from the CCU.

MACRO-INVERTEBRATES

Aim

To list and assess the relative abundance of macro-invertebrate taxa for a defined part of each ECN site.

Rationale

Macro-invertebrates are a very diverse group of organisms with a wide range of environmental tolerances and preferences and are generally abundant in freshwater habitats. Communities are therefore likely to show both qualitative and quantitative responses to a full spectrum of possible environmental changes. In most situations macro-invertebrates are also relatively easy to sample, qualitatively at least, and keys for the identification of most elements of the British fauna are readily available.

Such considerations have, for many years, led to the extensive use of macro-invertebrates in biological assessment of water quality. Water quality indices based on macro-invertebrates are generally derived from scores allocated to taxa according to their perceived tolerance, or intolerance of pollution (eg Woodiwiss 1964). The necessary level of identification varies between methods but the widely used BMWP score (Biological Monitoring Working Party 1981) requires only family level data.

RIVPACs (Wright *et al.* 1993) allows prediction of the fauna which would normally be expected to be present in a river site in the absence of pollution. This model thus allows a high degree of objectivity to be applied in the interpretation of biotic scores. Furthermore RIVPACs methodology may also be applied at any taxonomic level, from species upwards, and can be used to compute an index of environmental quality derived as a ratio of the observed community to that expected for relatively pristine conditions.

Methodologies for using macro-invertebrates to monitor water quality in rivers are thus well established but this is less true for still waters. Nevertheless certain groups, notably midges, have been shown to be very useful in systems of lake classification (Saether 1979) and subfossil remains of midge larvae have also been widely used in elucidating historical changes, both natural and anthropogenic, in lakes (eg Walker *et al.* 1991).

Abnormalities in the appearance of particular macro-invertebrate structures often result from environmental contamination by toxic chemicals. Most notably, high incidences of deformities in midges, mainly of their head capsules, have been linked to toxic pollution in both lakes and rivers (eg Warwick 1980). Archiving of material in ECN will allow such factors to be investigated in this and in other groups at some future time if a need becomes apparent and funds are available.

Equipment

Most sampling will be carried out using a long-handled pond-net of the type commonly used in RIVPACs surveys (Wright *et al.* 1993). This should either conform with the most recent specification for RIVPACs (Environment Agency 1997) or with the standard FBA pattern with a square aluminium frame of 257 mm side and a mesh size of 1000 µm (see Appendix I, page 96). A bag-depth of 500 mm, which avoids 'wash-back', is recommended but the standard bag with an average depth of 254 mm is acceptable. Multifilament polyester nets are preferred to monofilament nets since they are softer and easier to empty, although they are more easily damaged and manufactured to less precise tolerances. Damaged nets must be repaired or replaced before use. Details of the net used at individual sites must be recorded and sent to the CCU.

Location

The area to be sampled should be representative of the section of river or littoral zone of the lake and should, wherever possible, coincide with the area used for other ECN measurements, (eg macrophytes). It should be an area where the major habitat types of the littoral zone of the lake, or reach of a river, can be sampled within the pre-determined sampling time (see under Sampling, below). Sampling areas which may be influenced by atypical local influences such as bridges, weirs, artificial banks or cattle-drinking areas should be avoided. The size of the sampling area will depend on the size and character of the water body and is therefore not prescribed.

The location of the sampling point must be recorded as a NGR to 10 m and marked on the sketch map.

Data on a range of physical characteristics of rivers will be important for the interpretation of data collected on invertebrates, especially in the context of RIVPACs. Some of these will be gathered as part of the ECN Aquatic Macrophyte Protocol (see page 66). However, measurements of the following physical characteristics should be made at the same time as the invertebrate sample is taken:

- water width (width of water surface (±0.5m) at right-angles to the channel);
- water depth (as the average of depths (±0.1m) measured at points one-quarter, half and three-quarters of the distance across the stream channel).

If the location of the invertebrate sampling point does not correspond with the macrophyte sampling location, then a separate measurement of the substratum characteristics (see Aquatic Macrophyte Protocol, page 66 and Chapter 3, pages 103–106) should also be made.

Sampling

Detailed prescriptions of sampling methodology cannot be provided because the equipment used and the tactics adopted will vary with the site characteristics.

Sampling tactics should include both kick-sampling of the streambed or the littoral zone of the lake, hand-searching, and sweep-sampling of any vegetation.

The standard total sampling time for a site will be 3 minutes, the standard time used in RIVPACs. The proportion of the total time which is allocated to each habitat type is proportional to the estimated surface area occupied by that habitat category. In addition there should be one minute of hand-searching for species such as river limpets. The same habitats should be sampled on successive occasions. Samples from different habitats are not kept separate.

Dredge sampling may be used as the primary sampling method in deep rivers or lake margins where it is impossible to sample adequately by other means. The Medium Naturalist's Dredge, described by Holme and McIntyre (1971) is recommended for use in RIVPACs and a similar type should be used for ECN. This comprises a rectangular metal frame, of aperture size 457 mm x 203 mm (dimensions need not be exact but the same pattern is to be used on each sampling occasion) to which a net bag is attached. The bag has a mesh of 1000 µm and a depth of 600 mm. It is protected by an open-ended outer skirt, which is constructed of more robust material. A tow-rope is secured by shackles to two lateral arms, also connected by shackles to the short sides of the rectangular frame. Details of its construction are given by Holme and McIntyre (1971).

Five tows of the dredge are recommended. One throw should be almost parallel with the bank to collect marginal species. In rivers, the dredge should be thrown downstream, since recovery against the current reduces lift during retrieval. Over coarse or compacted substrata retrieval should be in a series of short, sharp movements to cause maximum disturbance. Over finer or less compact surfaces a more rapid, even retrieval will cause the dredge to skim efficiently through the upper layers of the substratum. If the retrieval is too rapid however, the dredge will lift off the bottom and few animals will be caught. Wherever possible dredge sampling should be supplemented by pond-netting of any marginal habitats not sampled adequately using the dredge. The several dredge samples are not kept separate but if both dredge and pond-net sampling are used, samples collected by the different methods are kept separate because of the bulk of the material, mainly detritus, gathered by the dredge.

It is important that for each site the methodology is determined at the outset and is not varied subsequently, otherwise between-year comparisons will be impossible.

For both running and standing waters three samples each year are preferred, taken during the periods March–May, June–August, and September–November, since this procedure has been shown to give a reasonably comprehensive species list. However, if the minimum prescription for running waters of two samples per year is followed, these should be taken during the first, and then during one of the other two periods, with the choice of the second sampling being consistent between years. The minimum prescription for standing waters of a single sample per year requires the sample to be taken during the spring period, (ie in March–May).

Sample treatment

If samples are to be sorted live they **must** be kept cool in a refrigerator or cool box in the field and in a refrigerator in the laboratory. They **must** be sorted within 48 hours of collection.

Ideally, however, samples should be preserved in the field using 10% formalin (4% aqueous formaldehyde), preferably immediately after collection to prevent carnivores present in the sample from eating other specimens. The fixative hardens the cuticle of insects and oligochaetes and reduces the chances of disintegration during handling and storage. Fixative can be added either in the concentrated form, from small bottles stored in each sample container, or in a dilute form (10% formalin) from a suitable jerry can. In-house procedures for using formaldehyde are provided by the Environment Agency (1997). These procedures have been tested to meet statutory safety standards (COSHH); however, every laboratory using these procedures, or other procedures authorised by their own laboratory, must carry out its own safety assessment, tailored to its own particular conditions and facilities.

If concentrated fixative is used, put approximately 100 ml of undiluted formalin (40% aqueous formaldehyde) in a 150 ml screw-topped bottle in the laboratory, using a fume cupboard or fume extractor. Place a bottle of fixative in each sample container. In the field add sufficient fixative to the sample to result in a 10% formalin solution, taking into account the volume of the water sample. Replace the cap on the bottle containing the unused formalin and replace it in the sample container. This procedure must take place outside, in a well-ventilated area and **not** inside a vehicle. Adherence to this procedure ensures that the formalin is always double-sealed, prevents large volumes of fixative being carried in the same container and limits the total volume being carried to that required for sampling. Protective gloves must always be worn when handling concentrated formalin.

If dilute fixative from a jerry can is used, this is added to the sample in a well-ventilated area and **not** inside a vehicle.

The formalin is distributed through the sample by gently tumbling the container, having first made sure that the cap is secure. Some air must be left in the container to ensure that mixing is thorough and this must be done in a well-ventilated area or in a fume cupboard in the laboratory.

Samples must be left in fixative at least overnight to ensure that they have been thoroughly penetrated by the fixative. Subsequently samples may be left in formalin until they are to be sorted, or the fixative can be thoroughly washed out and the samples stored in 70% alcohol (industrial methylated spirit). Washing must be carried out in a fume cupboard or using a fume extractor.

Preservation in alcohol after fixation

If fixed samples are to be kept for more than a few months before sorting, they must be preserved by transferring them to alcohol. A 70% aqueous solution of Industrial Methylated Spirit (IMS) and 5% glycerol is needed for effective preservation. It is necessary to ensure that the residual alcohol concentration is adequate after allowing for the penetration of organic matter and dilution by displaced water; this is achieved either by changing the alcohol several times or by using alcohol with an initial concentration greater than 70%. The addition of sufficient 90% alcohol to provide an overlying volume roughly twice that of the sample will usually be adequate.

Sorting, identification and counting of specimens

Samples must be well-washed with water before sorting, using a fume cupboard or fume extractor for the purpose. All animals retained by a sieve of mesh size 500 µm are to be regarded as part of the sample and should be identified using the following criteria.

As far as possible all the invertebrates in the samples should be identified to **species** level; in cases where the necessary level of expertise is not available, **minimum** acceptable levels of identification are given in Appendix II (page 96). The revised checklist and coding system (Biological Dictionary Determinand Working Group 1989) should be used as the standard for ECN macro-invertebrates; this allows for identification at mixed taxonomic levels. All specimens should be archived after preservation in 70% alcohol in small vials; the addition of formaldehyde is not necessary at this stage. It is recommended that after sorting, all samples should be re-constituted, preserved, well labelled and archived.

Absolute numbers, or an estimate of absolute numbers (±10%) through sub-sampling, should be determined for each taxon identified. This will allow subtle changes in community structure to

be detected. For the purposes of RIVPACs, an estimate of abundance at family level (with the exception of Nematoda, Oligochaeta and Hydracarina which should be reported in these 3 groups) should also be made using a log scale of abundance of 1–5 as follows:

1	1–9 animals
2	10–99 animals
3	100–999 animals
4	1000–9999 animals
5	>10000 animals

Author

L. C. V. Pinder

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Appendix I

Supplier

Details of suppliers of the standard FBA hand net (Model HN1) and other equipment are obtainable from the CCU.

Appendix II

Taxonomic identification levels required as a **minimum** for ECN. Table after Doughty (1989).

Phylum	Class	Sub-class	Order	Identification level
Platyhel-minthes	Turbellaria		Tricladida	Species except *Polycelis nigra/ tenuis* and *Dugesia lugubris/ polychroa*
Nematoda				Phylum
Annelida	Oligochaeta			Family
	Hirudinea			Species
Mollusca				Species except *Sphaeriidae* (genus)
Arthropoda	Crustacea	Malacostraca		Species
	Arachnida		Acarina	"Hydracarina"
	Insecta		Ephemeroptera	Species
			Plecoptera	Species
			Odonata	Species
			Hemiptera	Family
			Coleoptera	Family except Elminthidae (species)
			Megaloptera	Species
			Trichoptera	Species except *Glossosoma, Agapetus, Wormaldia* (genus) and Hydroptilidae (family)
			Diptera	Family except *Tipula, Eloeophila, Dicranota, Hexatoma, Pedicia, Atherix, Limnophora* (genus)

Chapter 3 ECN DATA REPORTING

Introduction

Section 1 of this chapter lists the measurement variables and results generated by each ECN Freshwater Protocol. An overview of procedures for data handling and formats for transfer of data to the CCU is given in Section 2. Documentation giving detailed specifications for data transfer for each individual protocol is not provided here, but may be obtained from the CCU on request.

Each sample or recording occasion and associated measurements are uniquely identified in space and time by:

- Site Identification Code, (eg R10) (see Appendix I, page 116, for a list of codes).
- Core Measurement Code, (eg FWC) (see Appendix I, page 116, for a list of codes).
- Location Code, (eg 01) Each ECN Site allocates its own code to replicate sampling locations for each core measurement (eg FWC 01, FWC 02 for different surface water collection points).
- Sampling Date (/time), (eg 10-MAR-1999) Date on which sample was collected or data were recorded. This will include a time element as part of the unique identifier where sampling is more frequent than daily (eg for core measurement FWD).

Standard recording forms for use in the field have been designed where required for selected protocols and can be obtained from the CCU. The use of computerised forms and mapping in the field is encouraged where sites have access to field computers, provided that output can be translated into ECN standard format; the development of these systems will be monitored for future ECN standards in computerised data capture.

All recorded data should be accompanied by the name of the person responsible for sampling/recording and also for sample identification where appropriate, as described in the detailed data transfer documentation available from the CCU. Any number of pre-defined quality codes (see Section 2.4, page 113 and Appendix II, page 117) may be associated with each sample or recording occasion, and data may also be accompanied by free-format text descriptions of problems which might affect its quality. Information provided during the first year of monitoring should

include grid references of the locations of point-based surveys, and maps showing the locations of transect- or area-based surveys. These will be incorporated into the ECN GIS.

The measurement variables listed for each core measurement in Section 1 below are those required for an individual instrument or sampling location at a single site. Note that the Site ID, Core Measurement Code, and Location Code explained above are required to identify every set of data, but are not repeated in the listings below in order to save space. Superscripts in the following tables refer to the Notes section associated with each Core Measurement.

1. Specification of results and recording conventions

1.1 Core measurement: Surface water discharge (FWD protocol)

The following variables are recorded automatically every 15 min at river sites:

Variable	Units	Precision of recording
Recording (Sampling) date		
Recording (Sampling) time	GMT (24h)	1 min
Stage (average)	m	0.001
Discharge (average)	$m^3 S^{-1}$ (cumecs)	0.001

1.2 Core measurement: Freshwater physical and chemical measurements – manual sampling (FWC protocol)

The following variables are recorded at a recommended frequency of weekly for rivers and fortnightly for lakes.

Measurement variable	Determinand code[1]	Units	Reporting precision	Recommended limit of detection[2]
Sampling Date	–			
Sampling Time	–	GMT (24–h)		
Water level	–	m	0.001	
pH[3]	PH	pH scale	0.01	
Suspended Solids[4]				
Dry weight:	SUSS	$mg\ l^{-1}$	3 sig. figs.	2 $mg\ l^{-1}$
Ash-free dry weight:	SUSSAF	$mg\ l^{-1}$	3 sig. figs.	2 $mg\ l^{-1}$
Turbidity[5]	TURB	NTU	0.01	–
[1,]Secchi disc[5]	SECCI	m	0.1	–
Temperature[6]	TEMP	°C	0.1	–
Conductivity[7]	CONDY	$\mu S\ cm^{-1}$	3 sig. figs.	1 $\mu S\ cm^{-1}$
Dissolved Oxygen[6]	DISOX	$mg\ l^{-1}$	3 sig. figs.	0.1 $mg\ l^{-1}$
Ammonium: NH_4–N	NH4N	$mg\ l^{-1}$	3 sig. figs.	0.01 $mg\ l^{-1}$

continued...

Measurement variable	Determinand code[1]	Units	Reporting precision	Recommended limit of detection[2]
...continued				
Total Nitrogen	NTOT	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Nitrate: NO_3–N	NO3N	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Nitrite: NO_2–N	NO2N	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Alkalinity ($CaCO_3$)	ALKY	mg l^{-1}	3 sig. figs.	0.02 mg l^{-1}
Chloride	CL	mg l^{-1}	3 sig. figs.	0.05 mg l^{-1}
[L]Total organic Carbon	CTOT	mg l^{-1}	3 sig. figs.	0.1 mg l^{-1}
[L]Particulate organic Carbon	CPART	mg l^{-1}	3 sig. figs.	0.1 mg l^{-1}
[R]Biological Oxygen Demand	BOD	mg l^{-1}	3 sig. figs.	1 mg l^{-1}
Total Phosphorus	PTOT	mg l^{-1}	3 sig. figs.	0.005 mg l^{-1}
Particulate Phosphorus	PPART	mg l^{-1}	3 sig. figs.	0.005 mg l^{-1}
Phosphate (soluble reactive):PO_4–P	PO4P	mg l^{-1}	3 sig. figs.	0.005 mg l^{-1}
Silicate: SiO_2	SIO2	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Sulphate: SO_4–S	SO4S	mg l^{-1}	3 sig. figs.	0.005 mg l^{-1}
Sodium-dissolved	NADIS	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Sodium-total[8]	NATOT	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Potassium-dissolved	KDIS	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Potassium-total[8]	KTOT	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Calcium-dissolved	CADIS	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Calcium-total[8]	CATOT	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Magnesium-dissolved	MGDIS	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Magnesium-total[8]	MGTOT	mg l^{-1}	3 sig. figs.	0.01 mg l^{-1}
Aluminium-total[8]	ALTOT	µg l^{-1}	3 sig. figs.	10 µg l^{-1}
Aluminium-labile[9]	ALLAB	µg l^{-1}	3 sig. figs.	10 µg l^{-1}
[R]Tin-dissolved	SNDIS	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
[R]Tin-total[8]	SNTOT	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
Manganese-dissolved	MNDIS	µg l^{-1}	3 sig. figs.	50 µg l^{-1}
Manganese-total[8]	MNTOT	µg l^{-1}	3 sig. figs.	50 µg l^{-1}
Iron-dissolved	FEDIS	µg l^{-1}	3 sig. figs.	50 µg l^{-1}
Iron-total[8]	FETOT	µg l^{-1}	3 sig. figs.	50 µg l^{-1}
[R]Vanadium-dissolved	VDIS	µg l^{-1}	3 sig. figs.	4 µg l^{-1}
[R]Vanadium-total[8]	VTOT	µg l^{-1}	3 sig. figs.	4 µg l^{-1}
[R]Nickel-dissolved	NIDIS	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
[R]Nickel-total[8]	NITOT	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
[R]Mercury-dissolved	HGDIS	µg l^{-1}	3 sig. figs.	0.1 µg l^{-1}
[R]Mercury-total[8]	HGTOT	µg l^{-1}	3 sig. figs.	0.1 µg l^{-1}
[R]Copper-dissolved	CUDIS	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
[R]Copper-total[8]	CUTOT	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
[R]Zinc-dissolved	ZNDIS	µg l^{-1}	3 sig. figs.	2 µg l^{-1}
[R]Zinc-total[8]	ZNTOT	µg l^{-1}	3 sig. figs.	2 µg l^{-1}
[R]Cadmium-dissolved	CDDIS	µg l^{-1}	3 sig. figs.	0.1 µg l^{-1}
[R]Cadmium-total[8]	CDTOT	µg l^{-1}	3 sig. figs.	0.1 µg l^{-1}
Lead-dissolved	PBDIS	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
Lead-total[8]	PBTOT	µg l^{-1}	3 sig. figs.	1 µg l^{-1}
Arsenic-total[8]	ASTOT	µg l^{-1}	3 sig. figs.	10 µg l^{-1}
For each determinand:				
Laboratory Code[10]				
Limit of Detection Code[11]			character code (<)	
Analysis Date				

Notes

The prefixes (R) and (L) before the determinand names above indicate that the analysis is to be performed for rivers only or lakes only, respectively. Where no prefix occurs, the determinand applies to both rivers and lakes.

(1) These codes should be used within the analytical dataset exactly as given in the Table above. Any additional determinands to be included may be allocated codes by agreement with the ECN Data Manager.

(2) These limits of detection are those recommended by the ECN Statistical and Technical Advisory Group as necessary for the detection of environmental change in the listed determinands.

(3) pH should be measured (or compensated for) at 20°C.

(4) Suspended Solids: Dry weight should be determined at 105°C ±5° and ash-free dry weight should be determined at 500°C ±20°.

(5) Turbidity and Secchi disc are alternatives to Suspended Solids.

(6) Lake profiles: Temperature and Dissolved Oxygen should be recorded at depths considered appropriate to the profile of each particular lake. Information about recording depths should be provided and a numeric suffix to the TEMP and DISOX determinand codes (eg TEMP1, TEMP2, etc) used to identify each depth position.

(7) Conductivity should be measured (or compensated for) at 25°C.

(8) Please note that 'total' implies analysis of the unfiltered sample. If the laboratory routinely filters samples and can only provide 'total dissolved', then the code xxTOTD, where xx is the symbol for the metal, should be used. For example: ALTOTD for total dissolved Aluminium.

(9) Labile Aluminium should only be measured at sites where there is a record of the pH ever having been less than 5.5.

(10) The Laboratory Code provides the link with the laboratory methods information (see below) to be supplied by freshwater organisations for each of their laboratories. The code should incorporate the organisation acronym where possible and should be agreed the ECN Data Manager.

(11) Where the value of a particular determinand falls below the limit of detection (LOD) for the method, the value of the determinand should be given as the LOD value, and the LOD code set to the character <. Where the value is at or above the detection limit this code should be left null.

Laboratory methods information

Details of analytical methods used by each laboratory involved in ECN should be submitted to the ECN Data Manager. The information is stored in the ECN meta-database and linked with the data *via* the Laboratory Code, Determinand Code and Date range. When any details change, a new record should be submitted by the laboratory and will be added to the database. Aspects of the analysis such as instrument maintenance, calibration, drift, and

training of staff will be under the control of the laboratory. The text format for submitting methods information is illustrated below, using nitrate as an example:

Organisation	NERC
Laboratory	ITE, Merlewood
Laboratory Code[1]	ITE-ME
Substance determined	Nitrate
Determinand code	NO3N
Basis of the method	Chemically Suppressed Ion Chromatography
Types of sample	Stream water (FWC)
Typical concentrations	FWC: 0.50
Volume for analysis	10 ml
Calibration range	0.01 to 10 mg l^{-1} – slight deviation from linearity corrected for by using 3rd-order regression.
Method of measurement	Peak area using integration/data system.
Results reported	3 sig figs as N(mg l^{-1})
Detection limit[2]	0.01 mg l^{-1}
Within batch std. devn. (mid range)[3]	2% rsd
Interferences	None
Internal QC measure	CUSUM quality control chart
Accuracy measure	AQUACHECK
Method	Dionex 2002i ion chromatograph with 50 µl injection loop, auto-sampler and sample load pump. Columns–AG4A–SC & AS4A operated with an anion micro-membrane suppressor and using an eluent mixture of 0.15 mM $NaHCO_3$/2mM Na_2CO_3 at 1.8 ml min^{-1}
Reference	Merlewood Lab method 3.7.5
Method used from date	11-NOV-1992 (the date on which analysis commenced using this method)
Method used until date	(the final date on which this analysis was used – leave blank if current)

Notes

(1) The Laboratory Code should incorporate the organisation acronym where possible. A code should be agreed with the ECN Data Manager.

(2) The detection limit is defined as 4.65 within-batch standard deviation of the blank or a solution with a concentration close to the blank when no signal is detectable from the blank (n = 10).

(3) A within-batch standard deviation in excess of 5% is unlikely to be acceptable.

1.3 Core measurement: Freshwater physical and chemical measurements– automatic sampling (FWA protocol)

The following variables are recorded automatically every hour:

Variable	Units	Precision of recording
Recording (Sampling) date		
Recording (Sampling) time	GMT (24h)	1 min
pH (average)	pH units	0.1
Temperature (average)	°C	0.1
Conductivity (average)	µS cm^{-1}	0.1
Turbidity (average)	NTU	1

1.4 Core measurement: Phytoplankton (FPP protocol)

The following variables are recorded from samples taken at a recommended frequency of weekly for rivers (chlorophyll only) and fortnightly for lakes (chlorophyll and species concentrations):

Variable	Units	Precision of recording
Sampling date		
Sampling time	GMT (24h)	1 min
Phytoplankton chlorophyll analysis:		
Chlorophyll *a*	µg l^{-1}	3 sig. figs.
Analysis date		
Species concentration (Lakes only) for each species present:		
Species code	8-digit code[1]	(eg 13080100)
Species name	genus species	(eg *Asterionella formosa*)
Species type	2-character code[2]	
Concentration	indivs ml^{-1}	1
	or mm ml^{-1} if filamentous	1

Notes

[1] ECN uses the Whitton *et al.* (1998) coded list of freshwater algae. A machine-readable version of this list is available from the NERC Land-Ocean Interaction Study (LOIS) Web site: http://www.nwl.ac.uk/~loissys/algal_coded_list.htm, or *via* the CCU.

[2] Phytoplankton species are categorised as:
CE – Cellular
CO – Colonial
FI – Filamentous
This code determines which units of measurement are used for reporting concentration.

The following variables are recorded at a recommended frequency of annually for rivers and once every two years for lakes:

1.5.1 Lakes

According to the protocol, the survey should be repeated at a number of sampling locations (centred on 'sampling points') around the lake. Each of these locations should be allocated a different FMA Location Code (eg FMA 01, FMA 02, FMW 03, etc) as described in the introduction to this chapter.

i. Shoreline Survey

Variable	Units	Precision of recording
Sampling date		
Width (W) of survey area		0.1
Sampling depth (at distance W from the shore)		0.1
Lake level		0.1
For each 10 m shoreline section:		
Section ID	2-character code S1 to S10	
Survey method	1-character code: W = Wading B = Boat E = Estimated from shore	
Substrate categories[2]	% in each category	
Shading categories[4]	% in each category	
and then for each species present:		
Species code	6-digit code[7]	(eg 382901)
Species name	genus species	(eg *Iris pseudacorus*)

ii. Transect Survey

Variable	Units	Precision of recording
Sampling date		
Compass bearing	degrees	
Max. depth of vegetation growth	m	0.1
Secchi disc depth (at deepest point of transect)		0.1
Limit of macrophyte growth (distance from shore)		0.1

continued....

Variable	Units	Precision of recording
...continued		
For each transect point:		
Transect Point ID	2-character code (T1 to Tn)	
and then for both Port and Starboard:		
Transect side (Port or Starboard)	1-character code: P or S	
Sample Depth	m	
Substrate (dominant category)	2-character code[2]	
Total plant cover	%	10
and then for each sampling method (Ekman grab, circular Plot, and Rake grapnel):		
Method code	1-character code: E, P or R	
and then for each species present:		
Species code	6-digit code[7]	(eg 364701)
Species name	genus species	(eg *Menyanthes trifoliata*)

1.5.2 Rivers

Variable	Units	Precision of recording
Sampling date		
For each 10 m river section:		
Section ID	2-character code S1-S10	
Survey method	1-character code: W = Wading B = Boat E = Estimated from bank	
Average width of channel	m	0.1
Depth categories[1]	% in each category	1
Substrate categories[2]	% in each category	1
Habitat categories[3]	% in each category	1
Shading categories[4]	% in each category	1
Water clarity categories[5]	% in each category	
Bed stability categories[6]	% in each category	
and then for each species present:		
Species code	6-digit code[7]	(eg 362701)
Species name	genus species	(eg *Filipendula ulmaria*)
Cover estimate	%	1

Recording forms

Standard recording forms for macrophyte surveys are available from the CCU.

Notes

(1) Depth categories are as follows:

1 <0.25 m
2 0.25 m–0.5 m
3 >0.5 m–1 m
4 >1 m

(2) Substrate categories are as follows:

B	BEDROCK	exposure of underlying rock not covered by alluvial deposits
BC	BOULDERS/COBBLES	>64 mm; half-fist or larger
PG	PEBBLES/GRAVEL	> 2–64 mm; half-fist to coffee granule size
S	SAND	>0.0625–2 mm; smaller than coffee granules and unlike silt/clay, abrasive to hands
SC	SILT/CLAY	<0.0625 mm – have a soft texture.
P	PEAT	dead vegetation undergoing bacterial decay in stagnant deoxygenated water. Strictly pure peat, not fine peaty deposits over more substantial substrate.

(3) Habitat categories are as follows:

P	POOL	A discrete area of slow flowing water, usually relatively deeper than surrounding water, between faster flowing stretches, as in a sequence of riffle-pool-riffle. Pools are deep and often turbulent, scoured during spate flows.
RI	RIFFLE	Fast flowing, shallow water whose surface is distinctly disturbed.
RU	RUN	Fast or moderate flowing, often deeper water whose surface is rarely broken or disturbed except for occasional swirls and eddies.
S	SLACK	Deep, slow flowing water, uniform in character.

(4) Shading categories are as follows:

N	NONE	No shading
B	BROKEN	Some direct sunlight hits the water surface in the shade-affected area when sun is directly overhead.
D	DENSE	5% or less of the shade affected area receives direct sunlight when the sun is directly overhead.

(5) Water Clarity categories are as follows:

CR	CLEAR	Channel substrate is clearly visible at all depths, as are macrophyte species.
CY	CLOUDY	Slightly discoloured with a moderate suspended solids load and partially

		reduced light penetration. All clumps of macrophyte species can be located on the substrate of the river channel but the view of them is partially distorted. A small piece/single shoot of a macrophyte species may be missed.
T	TURBID	Strongly discoloured, carry a heavy suspended solids load and greatly restrict light penetration. The channel bed is obscured and submerged macrophyte species are indistinguishable from substrate and water. This will lead to a reduction in accuracy and efficiency of the method.

(6) Bed Stability categories are as follows:

SF	SOLID/ FIRMLY BEDDED	(eg bedrock/compacted clay), increased flow has little effect.
ST	STABLE	(eg boulders/pebbles/gravel), unlikely to be significantly affected by increased flows.
U	UNSTABLE	(eg gravel/sand/silt/mud), likely to be dislodged by increased flows.
SS	SOFT/SINKING	(eg deep silt/mud), making channel unwadeable. Bank stick penetrates easily into substrate.

(7) ECN currently uses the list of macrophyte species and coding system given in Holmes *et al.* (1978), with the addition of some large algal species from Whitton *et al.* (1998) as follows:

Batrachospermum spp
Cladophora spp
Enteromorpha spp
Hildenbrandia rivularis
Lemanea fluviatilis
Vaucheria spp
Chara aspera
Chara baltica
Chara braunii
Chara canescens
Chara connivens
Chara contraria
Chara curta
Chara denudata
Chara fragilifera
Chara globularis
Chara hispida
Chara intermedia
Chara muscosa
Chara pedunculata

Chara rudis
Chara tomentosa
Chara virgata
Chara vulgaris
Lamprothamnium papulosum
Nitella capillaris
Nitella confervacea
Nitella flexilis
Nitella gracilis
Nitella hyalina
Nitella mucronata
Nitella spanioclema
Nitella tenuissima
Nitella translucens
Nitellopsis obtusa
Tolypella glomerata
Tolypella intricata
Tolypella nidifica
Tolypella prolifera

A machine-readable version of the coded macrophyte list can be obtained from the CCU.

1.6 Core measurement: Epilithic diatoms (FDT protocol)

Samples should be taken at a recommended frequency of 3 times a year for both rivers and lakes.

At the present time, diatom samples are archived at the ECRC, University College London, for future analysis, and no data specifications apply. ECN acquires information on sites, locations and sampling dates for diatom sampling directly from the ECRC. Please refer to the FDT protocol (page 81) for information on labelling of samples.

1.7 Core measurement: Crustacean zooplankton (FZP protocol)

The following variables are recorded from samples taken at a recommended frequency of fortnightly, at lake sites only:

Variable	Units	Precision of recording
Sampling date		
Sampling time	GMT (24h)	1 min
Net mesh size	µm	1
Net bag depth	mm	1
Net mouth area	mm^2	
Settled volume	ml	

continued...

Variable	Units	Precision of recording
For each species present:		
Species code	8-digit code[1]	(eg 31130201)
Species name	genus species	(eg *Eudiaptomus gracilis*)
Concentration	indivs l^{-1}	

Notes

[1] ECN uses the 'revised Maitland' coding system (Furse *et al.* 1989) used by RIVPACs. A list of crustacean zooplankton, which forms a sub-set of the RIVPACs list, has been provided by the Institute of Freshwater Ecology; a copy of this species list and associated RIVPACs codes can be obtained from the CCU. A copy of the complete RIVPACs coding system may be obtained through the CCU.

1.8 Core measurement: Freshwater macro-invertebrates (FIN protocol)

The following variables are recorded from samples taken at a recommended frequency of three times per year for both rivers and lakes:

Variable	Units	Precision of recording
Sampling date		
Sampling start time	GMT (24hr)	1 min
Sampling duration	mins	1 min
Sampling method	1 character code: P=Pond net D=Dredge	
Net mesh size	µm	
Net bag depth	mm	1
Net mouth area	mm^2	1
Water width	m	0.1
Water depth (average)	m	0.1
For each species present:		
Species code	8-digit code[1]	(eg 04320704)
Species name	genus species	(eg *Mesostoma tetragonum*)
Numbers of individuals	count[2]	
For each family[3] present:		
Family code	8-digit code[1]	
Family name		
Abundance class	1-digit code[4]	

Notes:

[1] ECN uses the 'revised Maitland' coding system (Furse *et al.* 1989) used by RIVPACs. A copy may be obtained through the CCU.

(2) This may be an estimate (±10%) by sub-sampling for large numbers of individuals.

(3) Abundance class should be determined at family level, except for Nematoda, Oligochaeta and Hydracarina for which abundance class should be recorded in these 3 groups.

(4) The species abundance coding system is as follows:

1 1 to 9 animals
2 10 to 99 animals
3 100 to 999 animals
4 1000 to 9999 animals
5 >10000 animals

2. Guidelines and formats for transfer of freshwater data to the CCU

This section describes the general procedures used in transferring machine-readable data to the CCU for validation and input to the central database. Detailed documentation describing the specific transfer formats for each core measurement is not provided here, but can be obtained from the CCU.

ECN has adopted the term 'core measurement' to mean an aspect of the environment on which a set of measurements will be made – for example: Macro-invertebrates, Zooplankton, etc. Each ECN Site has been assigned a 'Site Identification Code', and each ECN Core Measurement (or sub-category of a core measurement) a 'Core Measurement Code' which will be referenced in the database and in datasets transferred to the CCU. These codes are listed in Appendix 1, page 116.

2.1 Data transfer media

Data are sent over the Internet by electronic mail (e-mail), but may also be sent by diskette if no network connection is available.

2.1.1 Transfer by electronic mail

Data should be sent by e-mail to: ECN@ITE.AC.UK.

Data may be e-mailed as a set of dataset messages, or as a single message with dataset attachments. Each dataset should contain data for only one ECN core measurement, should begin with header information (see section 2.2.1, page 111) and terminate with END on a separate line. The Subject field of the message should describe uniquely the contents of the e-mail, including in particular the Site Code(s) or organisation/region name and the Core Measurement Code(s) to which the datasets relate, and the date range. For example: "ECN data: EA-North West FWC Mar-May 1999".

The first e-mail message of a set, or the message carrying attached datasets, should provide the following information:

- a list of data messages to follow, or dataset attachments;
- the Site Codes and Core Measurement Codes in the accompanying datasets;
  the name and address (eg as an e-mail 'signature') of the person sending the data;
  any additional text information necessary to qualify each dataset (see section 2.4, page 113).

2.1.2 Disk transfer

Disks should be sent to: ECN Data Manager, Merlewood Research Station, Grange-over-Sands, Cumbria, LA11 6JU, UK.

IBM-format 3.5 inch diskettes should be used, labelled with:

- Site Codes and Core Measurement Codes;
- name and organisation of the person sending the disk;
- date sent.

Each datafile should contain data for only one ECN Core Measurement, and begin with header information, as described in section 2.2.1 below. Data file names should reflect the data they contain.

The disk should also include a file called inform.txt, which contains the name and address of the person sending the disk, the name of each datafile and its respective Core Measurement Code and dates, followed by any text necessary to qualify the data in that datafile (see section 2.4, page 113).

2.2 Data file format

Each data record is uniquely identified in space and time within the ECN database, using the Site Code, Core Measurement Code, Location Code and Sampling Date(/time) as described in the introduction to this chapter. The Core Measurement and Location Codes together identify a particular sampling location within an ECN Site, (eg FWC 01, FWC 02 for different surface water sampling points, or FMA 01, FMA 02 for different macrophyte sampling locations). The logical structure of datasets is different for each ECN core measurement, and this affects the format for data transfer. For most transfer datasets, each individual data record will include a date(/time) reference – the Sampling Date(/time) – as one of its key fields. A spatial reference to site, core measurement and location code must also be provided; this may either be part of the header information or one of the fields in the data record, depending on whether the dataset refers to a single location (eg hourly data from one automatic monitoring station), or more than one (eg different stream water sampling points). Additional codes are used in the data to identify replicate instrumentation, plots, samples etc at a single location. These format and structure details are provided in the respective data transfer documentation for each core measurement.

The wide variety of software systems in use by ECN organisations has made it difficult to standardise on specific software for data transfer. The most straightforward solution has been to standardise on ASCII text files in comma-separated format, which most software products are able to support. Data entry forms with automatic validation checks are being developed for use by those organisations without their own databases and associated data entry software.

2.2.1 Data file header

Each data file should normally begin with 4 lines of header information, as follows:

Measurement Code	(eg FIN)
Site Name(s)	(eg Lough Neagh, Lough Erne)
Site ID Code(s)	(eg L16,L17)
Location Code(s) contained in dataset	(eg 01,02,03) & any additional information required in the dataset*

* as specified in the detailed transfer documents for individual core measurement.

2.2.2 Data record format

The data transfer document for each core measurement gives details of the required standard format for data records: these are available from the CCU. A general principle is that data should be in 'free-format', with comma-separated fields in the order specified in the transfer document. Quality codes describing any problems relating to a given sampling date may be attached to each data record. Section 2.4 (page 113) describes the procedures for supplying quality codes and text in more detail.

2.2.3 Zero values

Data values of zero are equally as important as non-zero values, and should be transmitted to the ECN database in the same way. It is also important that the distinction between zero values and missing data (see section 2.3) is understood. For example, if there is no water in a precipitation collector at a given sampling date, the volume must be recorded as *zero*, not as missing.

2.2.4 Dataset continuity

A dataset sent to the CCU for a given core measurement and Location should continue logically from the final record of the last dataset sent, so that there are no gaps or overlaps. For example, if the final record of an automatic monitoring station dataset is 11.00 on the 1st February, then the first record of the next dataset sent should be 12.00 on 1st February. If for some reason there are breaks

in the data, these should be explained in the information file or e-mail message (see section 2.4, page 113).

2.3 Missing data and non-standard sampling dates

2.3.1 Missing data fields

Data values should be recorded as 'missing' where a reading or sample could not be taken, (eg if an instrument has broken down). Missing data values should be recorded as 'null' fields by simply including the separating comma in the data record where otherwise the data value would be. It is most important that these separating commas appear in the correct place in the data record, otherwise it will not be clear which data field refers to which variable. Information about the reasons for missing data should be given either through the quality codes attached to the data records or, if no code is suitable, in the e-mail message or inform.txt file, accompanied by dates or date ranges (see section 2.4).

2.3.2 Missing data records

It is important that ECN samples or recordings are made on the standard sampling-due dates and according to the sampling periods specified in the protocols. However, there may be occasions where sampling or recording is not possible, and all data fields are missing. As a general rule, data records for **all dates on which sampling/recording is due**, even if missing, should be included in the dataset, with null data fields, and appropriate quality codes and/or text supplied (see section 2.4). Exceptions to this rule, where records may be omitted, are as follows:

if there are runs of more than 3 successive missing sampling-due dates, for example through instrumentation failure. However, information on why dates are missing should be included in the email message or inform.txt file (see section 2.4);

if another date is substituted for the sampling-due date, for example, if a surveyor is prevented from making a recording because of bad weather but successfully attempts to make a recording the following day. In this case, include **only** the data record for the substitute date, **omitting** that for the sampling-due date. However, the quality code 222 "non-standard sampling date" should be attached to the substitute data record, and reasons given in the inform.txt file (see section 2.4);

laboratory analysis results. Only those data records for which a field sample has been provided should be included. (Information about missing samples will be provided through associated field sampling datasets.)

2.4.1 Supplying information about quality

It is important that ECN data are accompanied by information about quality. Standard operating procedures and target quality criteria are specified in the measurement protocols and specifications are stored in the meta-database. Wherever a value has been recorded using a different procedure or specification, or where other factors beyond direct control affect recording or sampling, information about these should accompany the data.

Where appropriate, pre-defined 'quality codes' which describe common sampling problems can be included on the end of data records, (ie they apply to a given sampling date at a single location). A list of quality codes has been drawn up (see Appendix II, page 117) which uses a 3-figure numeric sequence; codes are added to the list if problems continue to recur. Examples are listed below.

126 River/lake frozen – no sample.
227 Sample taken from lake outflow.
101 No sample/recording taken – equipment out of action/ unable to visit equipment.
222 Non-standard sampling date.
999 Free-text information is associated with this data record.
000 No problems with sampling/recording – no quality codes or text apply.

If a problem occurs with a particular measurement for which there is no existing code, then free text comments should be recorded on the field form and reported in the e-mail message or inform.txt file when transferring data to the CCU; quality code 999 should also be attached to the data record to indicate that text information has been supplied. New codes are allocated in consultation with the CCU if the reported condition recurs regularly, and a new list issued. Those quality codes particularly appropriate to a given core measurement are listed in its accompanying data transfer document. Any number of codes can be appended to a single data record. Quality code 000 should be used where quality issues have been considered, but no quality information applies (either as codes or text). This provides positive differentiation from the situation where information about quality has not been considered at all (which is assumed if no code at all appears at the end of a data record).

Where data fields relate to time-periods (for example temperature averaged over an hour from 5 min readings), the length of the time-period is clearly important. Where the time period is not explicit in the data record, but is assumed to be standard, for example, as is often the case for automatic instrumentation, it is particularly important that appropriate information is supplied about any non-

standard time periods due to omissions, instrumentation breakdown or in-operation between sampling dates/times.

2.4.2 Data checking and validation

It is most important that individual sites perform basic but fundamental checks on the dataset before it is sent in to the CCU. Examples are:

- data reported in the specified format;
- data fields in the specified order;
- missing fields correctly indicated;
- correct quality codes used where necessary.

Validation for categorical codes and numeric data ranges will be made as data are entered into the ECN database. However, values which fall outside the ranges will only be discarded if there is a clear explanation, such as instrumentation error, and corrections made where possible. If the reason is unclear, then the values will be stored, but qualified in the meta-database. For these reasons, recorders are asked not to alter data unless there is a clear explanation for error. Any alterations made on this basis (apart from typing and formatting errors), or any suspicions about the validity of the data, should be given in the e-mail message or information file.

2.5 Frequency of data transfer to CCU

How often data are transferred to the CCU at ITE Merlewood, and the time-lag between data capture and data transfer, will depend to some extent on the core measurement protocol. It is necessary to strike a balance between keeping the database as up-to-date as possible, validating data as quickly as possible, and maintaining a realistic level of workload for all those involved. In addition, the CCU has a responsibility to produce summary statistics and carry out analyses to meet agreed schedules. It is suggested that freshwater data should be sent 6-monthly in March (for the previous June–December period) and in September (for the previous January–June period). Information about frequency and time-lag for data transfer will be included in the respective data transfer documents.

2.6 Data receipt and data backup

Data sent to the CCU are acknowledged when received, and a validation report sent when the data are safely transferred into the ECN database. Disks will be returned to sites in batches. Suitable arrangements have been made for backing up the ECN database itself. However, it will be important to ensure that data are secure during the time between collection and entry into the database. For this reason, sites should ensure that they keep copies of the data, at least until the safe storage of the data in the database is

acknowledged. Sites are asked to keep hard copy recording forms for as long as is practicable, as an ultimate reference for any information which may have been missed when coding and entering data.

A. M. J. Lane
ECN Data Manager

References

Furse, M., McDonald, I. & Abel, R. 1989. *A Revised Coded Checklist of Freshwater Animals Occurring in the British Isles.* Biological Dictionary Determinand Working Group. London: Department of the Environment. Unpublished software.

Holmes, N.T.H., Whitton, B.A. & Hargreaves, J.W. 1978. *A Coded List of Freshwater Macrophytes of the British Isles.* Reading: Department of the Environment, Water Data Unit.

Whitton, B.A., John, D.M., Johnson, L.R., Boulton, P.N.G., Kelly, M.G. & Haworth, E.Y. 1998. *A Coded List of Freshwater Algae of the British Isles.* LOIS Publication No 222. Wallingford: Institute of Hydrology.

APPENDIX I ECN freshwater Site ID Codes and Core Measurement Codes

SITE IDENTIFICATION CODES – Freshwater Sites (1999)

Rivers	Lakes
R01 Eden (Cumbria)	L01 Upton Broad (Norfolk)
R02 Esk (North Yorkshire)	L02 Hickling Broad (Norfolk)
R03 Coquet (Northumberland)	L03 Wroxham Broad (Norfolk)
R04 Exe (Devon)	L04 Windermere (Cumbria)
R05 Wye (Gwent)	L05 Esthwaite (Cumbria)
R06 Lathkill (Derbyshire)	L06 Loch Leven (Tayside)
R07 Cringle (Lincolnshire)	L07 Scoat Tarn (Cumbria)
R08 Frome (Dorset)	L08 Llyn Llagi (Snowdonia)
R09 Bradgate Brook (Leicestershire)	L09 Lochnagar (Grampian)
R10 Bure (Norfolk)	L10 Loch Lomond (Strathclyde)
R11 Old Lodge (West Sussex)	L12 Loch Katrine (Central Scotland)
R12 Stinchar (Strathclyde)	L13 Loch Davan (Grampian)
R13 Lower Clyde (Strathclyde)	L14 Loch Kinord (Grampian)
R14 Allt a'Mharcaidh (Highlands)	L15 Loch Dee (Dumfries & Galloway)
R15 Spey (Grampian)	L16 Lough Neagh (Co. Down)
R16 Tweed (Borders)	L17 Lough Erne (Co. Fermanagh)
R17 Eden (Fife)	
R18 Cree (Dumfries & Galloway)	
R19 Faughan (Co. Londonderry)	
R20 Garvary (Co. Fermanagh)	
R21 Bush (Co. Antrim)	
R22 Trout Beck (Cumbria)	
R23 Coln (Gloucestershire)	
R24 Lambourn (Berkshire)	
R25 Eden (Kent)	
R26 Ewe (Highlands)	

FRESHWATER CORE MEASUREMENT CODES:

FWD	Surface Water Discharge
FWC	Physical and Chemical Variables – manual measurements
FWA	Physical and Chemical Variables – automatic measurements
FPP	Phytoplankton
FMA	Aquatic Macrophytes
FDT	Epilithic Diatoms
FZP	Crustacean Zooplankton
FIN	Macro-invertebrates

APPENDIX II ECN freshwater measurements: Quality Codes for survey

(Current at 7th June 1999)

100 No information available – data lost
101 No sample/reading taken – equipment out of action/unable to visit equipment
102 Sample lost or inadvertently discarded
103 Partial loss of sample
104 Sample frozen when collected
106 Snow during sampling period
108 Insects in sample
109 Leaves in sample
110 Soil in sample
111 Unidentified debris in sample
113 Sample discoloured
114 Bonfire in vicinity during sampling period
115 Heather burning in vicinity during sampling period
116 Forest fire in vicinity during sampling period
117 Straw burning in vicinity during sampling period
118 Crop spraying in vicinity during sampling period
119 Construction work in vicinity during sampling period
120 Liming in vicinity during sampling period
121 Change of land use in vicinity
126 River/lake frozen – no sample
127 River/lake dry – no sample
130 Plot/transect section not surveyed
131 Trampling during sampling period
132 Plot/transect section not accurately relocated
133 Evidence of disease in plot/transect section
134 Significant disturbance in plot/transect section
137 Flooding of survey area
138 Mowing of survey area
139 Muck/slurry/slag application
140 Application of chemicals (details should be supplied)
141 Grazing by sheep
142 Grazing by cattle
143 Grazing/browsing by deer
144 Grazing – other
145 Woodland Management – Coppicing
146 Woodland Management – Thinning
147 Woodland Management – Clear Felling
148 Woodland Management – Brashing
149 Wind-throw
163 Trampling by cattle during sampling period
168 Trampling by sheep during sampling period
169 High river flow following snowmelt
200 Adverse weather conditions affected sampling/recording

201 Biting insects affected sampling/recording
202 Failing light affected sampling/recording
203 No flow observed in river – standing water only
204 Material inadequately preserved
205 Supplementary samples taken
206 Unidentified material archived
207 River/lake stage iced up
208 Water sampling site cleared of weed/algae
222 Non-standard sampling date
223 Non-standard sampling time
224 Data edited – HYDROLOG code 2
225 Data suspect – HYDROLOG code 3
226 Data unvalidated – HYDROLOG code 4
227 Sample taken at lake outflow
228 Sample taken from jetty/dam
501 Laboratory – No sample
502 Laboratory – Sample lost or inadvertently discarded
503 Laboratory – Partial loss of sample
504 Laboratory – Sample discarded because of contamination
505 Laboratory – Insufficient sample for measurement
506 Laboratory – Measurement not made because of equipment failure
507 Laboratory – Sample pre-filtered
508 Laboratory – Significant deposit of black material on filter
509 Laboratory – Significant deposit of brown material on filter
510 Laboratory – Significant deposit of green material on filter
511 Laboratory – No separate acidified sub-sample for Al and Fe

APPENDIX III Key to abbreviations for measurement units

Abbreviation	Units
m	metre
cm	centimetre
mm	millimetre
µm	micrometre
l	litre
ml	millilitre
g	gram
mg	milligram
µg	microgram
h	hour
min	minute
s	second
yr	year
GMT	Greenwich Mean Time
^{o}C	degrees Celsius
NTU	Nephelometric Turbidity Units
indivs	individuals
mM	millimole
mm^2	square millimetre
m^3	cubic metre
$m^3\ s^{-1}$	cubic metres per second ('cumecs')
$\mu S\ cm^{-1}$	micro-Siemens per centimetre
$mg\ l^{-1}$	milligram per litre
$\mu g\ l^{-1}$	microgram per litre
$mm\ ml^{-1}$	millimetres per millilitre
$indivs\ l^{-1}$	individuals per litre
$indivs\ ml^{-1}$	individuals per millilitre
$ml\ min^{-1}$	millilitres per minute

Chapter 4 THE ECN DATABASE: FRESHWATER MEASUREMENTS

Introduction

The ECN database is an integrated system for storing data and meta-data from all ECN's core measurements from its network of freshwater and terrestrial sites. Much of the freshwater network data were already routinely collected and stored in different databases and in different structures across the seven organisations which participate in Freshwater ECN. These data are brought together, along with 'new' data captured specifically for the ECN programme, into standardised structures within the ECN database, to support the cross-disciplinary analyses necessary for the detection of environmental change.

Databases form the core information resource for long-term monitoring programmes like ECN, and should aim to provide a complete representation of all information gathered over their duration. This is becoming even more important as rapid developments in new technology for remote access mean that the use and interpretation of information rely less on personal contact with data providers. A meta-information system is an essential part of any such database: it is not sufficient simply to provide the data values themselves, but necessary to include their description, derivation, measurement parameters, and quality criteria. Long-term environmental research databases must be reliable and stable, secure over a long time-span, accessible but with access controls, and flexible enough to allow for spatio-temporal analyses of a range of variables.

Users of data on environmental change range from scientists to the general public. The ECN database is seen primarily as a long-term information resource for scientific research into the processes of environmental change. However, it also has an important role in providing UK Government departments and agencies with more immediate information about long-term trends and environmental extremes and early warning of changes which may influence policy or require immediate action.

The CCU is responsible for data handling and for the management and development of the database. Figure 4 gives an overview of the ECN data management system; its main components are:

- data input: data capture at ECN sites, transfer by e-mail and validation;
- database, meta-database and GIS;
- remote data access systems.

1. Data handling and database design

1.1 Data capture

ECN data capture for freshwater measurements requires mainly manual methods, recording on to standard field forms. Automatic methods are used to record 15 min river stage and discharge, and hourly pH, temperature, conductivity and turbidity measurements. Wherever possible and appropriate, existing data capture techniques and common coding schemes have been adopted to maintain ECN's comparability with other sectoral networks. Developments in robust computers for data entry in the field are being monitored for future use when resources allow.

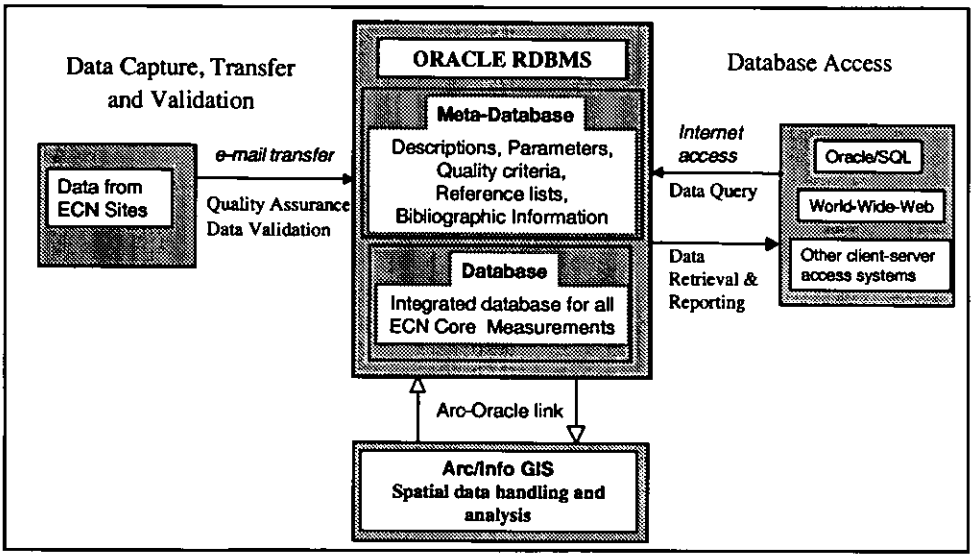

Figure 4. An overview of the ECN data management system

The catchments of ECN freshwater sites cover not only semi-natural environments but also intensively managed agricultural systems. Background data about changing land uses, management practices, chemical applications over the catchments and point-source discharges are acquired where available as an important adjunct to the ECN measurements. Aerial photography and remotely sensed imagery (satellite or air) are important sources of information about changing spatial patterns over time across ECN sites and their catchments; opportunities for using existing and specially commissioned remotely sensed imagery are exploited wherever possible.

1.2 Data transfer

Site Managers are responsible for sending data to the CCU in machine-readable form using prescribed formats. Chapter 3 (pages 97–119) explains how sites, measurements and sampling events are

identified, and specifies the sampling results, their units and precisions for each core measurement. Datasets should be sent in every 6 months in March and September *via* e-mail as the preferred medium for transfer, with IBM format diskettes as an alternative where sites have no Internet connection. The ECN dataset format is comma-separated data values transferred as ASCII files – a format which the vast majority of software can handle and which is easily transferred by e-mail. Standard data entry forms with built-in validation procedures are being developed for manually recorded data where in-house data entry systems are not already in use. In addition to the measurement values, the specifications for most datasets include pre-defined 'quality codes' (listed in Chapter 3, Appendix III, page 119) which describe factors affecting measurement on a particular sampling occasion, or affecting a particular instrument or sample. In addition, sites may send free-text information where existing quality codes are insufficient or inappropriate. The generic ECN format and method for transfer, including how to handle missing data and associated quality information, is provided in Chapter 3, Section 2 (page 109).

1.3 Data processing

Datasets are stored by the CCU in the form received and are logged by site, core measurement code and date, prior to processing. Receipt of e-mail datasets is acknowledged immediately; disk datasets generally await database input/validation, unless there is more than about two weeks' delay between receipt and further processing. Data loading, transformation and validation programs have been written for each dataset type. The time taken to process datasets is strongly affected by the type and number of errors they contain, and may vary between ten minutes and two days. Where possible, queries and problems are solved through communicating over e-mail, although if errors are numerous or particularly difficult to decipher, then a request is made for a repeat dataset to be sent. Sites are strongly encouraged to check their data thoroughly before despatch; form-based data entry with integral validation undoubtedly helps to minimise typing and formatting errors. Once processed and installed within the database, sites are sent an acknowledgement form and validation report which confirms input and reports any problems. Data validation methods are discussed separately under Section 2, Quality Assurance (page 125).

1.4 Database system and design

A central database with remote network access was considered the most appropriate model for ECN to ensure a fully integrated system with the required data quality and maintenance standards, whilst meeting the requirement for direct and rapid access to the data. The database uses relational database management software in the form of Oracle, with links to Arc/Info for spatial data handling; this runs on a Unix-based local-area-network with high-speed links to the Internet

for remote access and incoming data. The system provides an integrated storage and retrieval facility for all ECN data and associated meta-information. ECN's current strategy is to maintain a centrally managed core database with good remote access provision, and to establish links to other site-based and sectoral network databases using a distributed approach.

The design of any database must focus not only on the data and their interrelationships but on the purpose and requirements of the activity it is to support. Broadly, ECN anticipates three main types of data use:

scientific research, requiring access to high-resolution data, and the ability and freedom to define complex queries and analytical functions in space and time;
information browsing and retrieval, requiring guided access to ECN information and summary data for display, extraction and incorporation into reports;
access to interpreted information based on simple models showing the main trends and features of the data.

Where, as in the case of ECN, the styles of data are diverse and the range of potential uses difficult to define, the database system needs to be integrated, but as versatile as possible to allow new structures to be generated, new datasets to be incorporated when required and ultimately give users free but guided access to data. Ideally, ECN requires a fully integrated database, GIS and statistical analysis and modeling system, which can support links with programming languages for external applications. New software developments which have begun to break down the boundaries between these functionalities continue to be reviewed and incorporated where appropriate and when resources allow. However, the use of reliable, well-known, and well supported database software is of paramount importance for long-term security.

The core database stores raw data at the resolutions specified in the ECN Protocols. An associated summary database consists of monthly and/or annual summaries of these data, using summary statistics appropriate to each measurement, as advised through ECN expert committees. The database is logically divided into data and meta-data tables. Data for each sampling location for a given core measurement within an ECN site are regarded as a logical 'dataset' which is allocated a unique identifier. A central meta-data table stores information about each dataset. Associated meta-data tables hold linked information on units of measurement, quality criteria, quality codes and text relating to sampling occasions, and reference tables for coded fields, (eg species codes). The spatial and temporal dimensions of variables are important and affect the database structure: some measurements relate to an instance in time, (eg surface water samples), whilst others are cumulative values collected over a time period, (eg rainfall). Spatial data may relate to points, lines or areas, and in each case the location and spatial form need to be defined within the GIS.

Database security is an important consideration, to avoid corruption or loss of data through system faults and to protect against unauthorised access. Incremental back-ups of the database are made daily, a full back-up is made weekly, and monthly back-ups are kept for one year, off-site. Storage media are renewed regularly. Additional fail-safe devices, which maintain the status of the system and level of service for users in the event of disk crashes, are being considered. Access controls and security monitoring software are in operation to prevent unauthorised use.

2. Quality assurance in ECN

2.1 Introduction and terminology

Quality assurance is an essential part of any long-term programme, especially when comparisons in space and time and the ability to distinguish signal from noise, or real effects from measurement artifacts are crucial to its success. Data of poor or unknown quality are unreliable. It is important to set quality standards at the outset of a data-gathering exercise, but it is equally important to monitor how far those standards are met, and to ensure that this information accompanies the data for future use.

A number of different terminologies are commonly used to express different aspects of quality. For ECN purposes, the following terms seem the most appropriate, and are related to those used in the British and International Standards (British Standards Institution 1987, 1995) for describing 'product' quality.

Quality assurance: a term embracing all planned and systematic activities concerned with the attainment of quality

Quality objectives: the specification of target values for quality criteria

Quality control: the practical means of ensuring that quality objectives are met, as set out in the specification

Quality assessment (or quality verification): procedures for assessment of the degree to which quality objectives have been met – ideally providing *evidence* that they have been met – after data capture. This should be a system of monitoring, which feeds back into the quality control process to maintain quality targets.

2.2 Quality control and assessment

The ECN Protocols are standard operating procedures (SOPs) designed to ensure consistency in measurement methods across sites and over time. They incorporate target specifications for quality criteria such as accuracy and recording resolution, where appropriate. Specifications for other quality criteria such as completeness, lineage and logical consistency of datasets (FGDC 1994; CEN 1996) are implicit within the protocols and in the formats for data transfer (available from the CCU). Quality control procedures go hand-in-hand with SOPs and have been included in the Protocols, (eg correct handling of equipment and samples, maintenance schedules and calibration specifications, and unambiguous instructions for measurement and data handling).

Quality assessment should be regarded as a monitoring exercise to keep measurements 'on course' by feeding information back to the data capture stage. Where the measured feature can be kept, (eg archived invertebrate samples), or re-visited, (eg vegetation plots), the accuracy of identification may be assessed at a later date through sub-sampling by an independent 'expert'. Currently, ECN either uses experts to identify all invertebrate specimens centrally, or sends sub-samples to them for verification.

The quality of more ephemeral measurements such as meteorology or water quality can only be similarly assessed by running duplicate or parallel systems. Duplicate systems are expensive, and in practice assessment normally involves regular checks for instrument drift and recorder error. As part of its terrestrial site network, ECN runs manual daily weather stations (weekly at the less accessible sites) concurrently with automatic stations to provide some parallel records, and has regular maintenance schedules for equipment which help to maintain standards across the network and over time. Automatic water quality loggers will be subjected to the same kind of quality assessment.

2.3 Data validation

Data validation can be regarded as part of quality assessment and involves screening data for 'unacceptable values' which may have occurred at any stage during data capture and handling. Present ECN data validation software for incoming data performs numeric range checks, categorical checks, formatting and logical integrity checks, (eg on dates, number of samples, and links between datasets). Appropriate range settings for ECN variables have been selected following discussion with specialists in each field.

ECN adopts a cautious approach to discarding data on the principle that apparent errors may be valid outliers. Data values

identified by validation software as 'unacceptable' are treated in one of three ways:

where values are clearly meaningless due to a known cause, (eg an instrumentation fault, and cannot be back-corrected), the data are discarded and database fields set to null (no data);
where values are clearly in error, or out of range due to known calibration errors, and can be back-corrected, data are stored separately until the correction can be made;
where there is no straightforward explanation for outliers, the data are stored in the database, accompanied by meta-data 'flags' and associated text.

Sites are strongly encouraged to check their data before sending them to the CCU, but not to alter them unless a reason for error is clear, and in any case to inform the CCU of their actions.

The data validation checks described above are important 'first-pass' procedures, but they are relatively coarse and may fail to identify erroneous data within the valid range. An extreme example is a faulty instrument which generates values within the given range, but which records only two distinct values. More subtle problems may only be revealed through multivariate or time-series checks, based on known processes or expected patterns in the data. Procedures for implementing these as a 'second-pass' validation stage are currently being developed.

2.4 Laboratory practice

ECN sites send water samples to their own associated laboratories for analysis. The cost of standardising methods of analysis across all ECN laboratories is prohibitive, and organisations need to maintain their own continuity in methods for existing long-term runs of data. Each laboratory practises its own internal quality control, and most participate in national quality assurance schemes. In addition, ECN is considering conducting inter-laboratory trials using standard solutions, along similar lines to the system used within the terrestrial network whereby a standard solution sample accompanies each batch of water samples from the field. Details of the existing methods used in each laboratory are incorporated into the ECN meta-database, and linked directly to each analytical record.

2.5 Handling quality information in the meta-database

Target specifications for quality criteria are stored as meta-information alongside instrument and sampling details, and units of measurement. Any deviations from these specifications or from the sampling methods given in the ECN Protocols are recorded with time-stamps. Details of laboratory methods and associated detection limits are stored similarly. Missing data and outliers which have

been revealed by the validation exercise but which cannot be corrected (see section 2.3 above) are qualified, using pre-defined quality codes (listed in Appendix II of Chapter 3, page 117) or free-text descriptions. This information may be associated either with a particular sampling occasion, or with an individual measurement variable on a sampling occasion. Site managers also use these codes or free text to describe factors affecting sampling outside their control, instrument damage or site management effects. Results of quality assessment exercises, (eg laboratory trials or vegetation re-survey), are also incorporated. All meta-information may be linked directly with the data to which it relates.

3. Database access

3.1 Methods of access

In the past, large centralised databases have had a reputation for being relatively inaccessible and difficult to use. ECN's need to maintain close interaction between monitoring and scientific research means that database access is fundamental to the success of the programme. Although the ECN system has been centralised for reasons of integration and quality assurance, rapid developments in networking software over the past decade mean that this model no longer has the historically poor access implications, and the physical location of the database is less important. The challenge is to provide access modes to suit different styles of use and which can provide sufficient guidance and information about the system to enable it to be used with little or no initial learning process for the user.

General-purpose database query and retrieval methods are provided primarily for scientific users already familiar with SQL and with the ECN database structures. Users may access the database *via* 'Telnet' and use SQL directly, or use a PC client front-end which constructs the SQL from a Windows-style interface. However, this mode of access is unsuitable for users who require easy, guided access to the data without having to undergo prior training.

With the second type of user in mind, ECN has developed a 'tailored' interface to the ECN summary database using the World-Wide-Web (WWW). The addition of database links to standard Web information pages can generate a powerful information interface, enabling text, images and data to be presented together and allowing the user to progress from browsing information to guided data retrieval in a single system. ECN's Web pages (http://www.nmw.ac.uk/ecn/) incorporate a hyperlink to a database query, display and retrieval system. This enables authorised users to build their own database query by selecting any combination of ECN sites, core measurement variables and date ranges for instant generation of tables and graphs. Data may also be downloaded *via*

e-mail in 'column' format, for input to local software. Meta-data on the number of sampling events from which the summary data were derived may also be viewed, and are automatically downloaded with the data. The system (see Brocklebank *et al.* 1996) was revised in 1998, and further details can be obtained from the CCU.

ECN also provides access to 'real-time' data *via* the Web from an automatic weather station (AWS) at the Moor House/Upper Teesdale site in the north Pennines. Data are transmitted hourly *via* a modem link to the CCU and automatically displayed as graphs and tabulations. Direct links from AWS at other ECN sites are planned, as well as from other automatic monitoring instrumentation, (eg water quality loggers). Once these links are considered sufficiently reliable, they will be used to download data automatically into the database through the data validation and input software.

3.2 Data ownership and access agreements

ECN data are owned jointly by their originating sponsoring organisation and the NERC; the ECN sponsors have agreed a system of user licensing and authorisation for access to high-resolution ('raw') and summary data. Summary data are freely available *via* the Web interface. Application forms for access to the raw data are available *via* the ECN Web pages (http://www.nmw.ac.uk/ecn/request.htm) and are automatically e-mailed to the CCU on submission. They are then sent to the sponsoring organisations for consideration and, if access is permitted, users are asked to sign a licence agreement which defines the terms under which ECN data may be used.

A. M. J. Lane
ECN Data Manager

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Chapter 5 ORGANISATIONS SPONSORING ECN FRESHWATER SITES

Department of Agriculture for Northern Ireland (DANI)

The Department of Agriculture for Northern Ireland (DANI) advises the Secretary of State for Northern Ireland (in the Secretary of State's capacity as one of the four UK Agriculture, Fisheries and Forestry Ministers) on UK policies with particular reference to the implications for Northern Ireland.

The responsibilities of the Department of Agriculture are:

- the development of the agricultural, forestry and fishing industries in Northern Ireland;
- as lead Department for rural development in Northern Ireland;
- the provision of an advisory service for farmers, agricultural research and education;
  provision of a veterinary service and administration of animal health and welfare policies – agent of the Ministry of Agriculture, Fisheries and Food in the administration in Northern Ireland of schemes affecting the whole of the UK;
  involvement with the application to Northern Ireland of the agricultural policy of the EU.

Department of the Environment, Transport and the Regions (DETR)

The Department of the Environment, Transport and the Regions is a UK Government Department responsible for a wide range of policies and activities:

- housing – including private ownership and renting, the Housing Corporation, housing associations and local authorities;
  construction and property & buildings – including industry sponsorship, building regulations and the Building Research Establishment (BRE);
  regeneration - including inner cities, new towns and the European Regional Development Fund;
  countryside and wildlife – including the quality of life in rural areas and the protection and conservation of the countryside and its wildlife;
  environmental protection – including the water environment, the water industry, energy efficiency, environmental technology and the British Waterways Board (a nationalised industry);
- local government – including its structure and finance;
- planning – including land use planning guidance and the Planning Inspectorate (PINS).

DETR contributes to the ECN freshwater monitoring programme through its sponsorship of the UK Acid Waters Monitoring Programme; it is also a major sponsor of the database and statistical activities of ECN.

Department of the Environment for Northern Ireland (DOENI)

Environment and Heritage Service (EHS) is a Next Steps agency within the Department of the Environment for Northern Ireland, and has responsibility for implementing government policy on environment and heritage matters in Northern Ireland. The corporate aim is to "protect and conserve the natural and built environment and to promote its appreciation for the benefit of present and future generations".

The agency is committed to:

- controlling pollution of air, water and land;
- identifying and managing nature conservation sites;
- managing country parks, countryside centres and historic monuments;
- protecting and recording historic monuments and buildings;
- promoting awareness and appreciation of the environment and heritage;

  pursuing continuous improvement in the delivery of our services;

  ensuring effective use of available resources.

The UK Acid Waters Monitoring Programme (UKAWMN)

The UKAWMN, funded by DETR and DOENI (see above), is designed to monitor the ecological impact of acid deposition in areas of the UK believed to be sensitive to acidification. With more than nine years of regularly monitored environmental data, subject to rigorous quality control procedures, the UKAWMN database represents a unique time series for upland freshwaters in the UK.

The network consists of 11 lakes and 11 streams which are monitored chemically and biologically. The UKAWMN is co-ordinated by ENSIS, part of the ECRC at University College London. Data are collected, analysed and collated by several laboratories throughout the UK. All data are stored in a database managed by the Institute of Hydrology and ENSIS.

Environment Agency (EA)

The Environment Agency is a non-departmental public body established by the Environment Act 1995. It is sponsored by DETR (see above) with policy links to the Welsh Office and the Ministry of Agriculture, Fisheries and Food.

The EA's vision is for "A better environment in England and Wales for present and future generations."

The functions of the EA cover flood defence, water resources, pollution control, fisheries, navigation, recreation and conservation. Its principal aim is defined in the Environment Act is as follows:

"Discharging its functions the Agency is required so to protect or enhance the environment, taken as a whole, as to make the contribution that Ministers consider appropriate towards achieving sustainable development". Within this principal aim the EA is working to:

- achieve significant and continuous improvement in the quality of air, land and water, actively encouraging the conservation of natural resources, flora and fauna;
  maximise the benefits of integrated pollution control and integrated river basin management;
  provide effective defence and timely warning systems for people and property against flooding from rivers and the sea;
  achieve significant reductions in waste through minimisation, re-use and recycling and to improve standards of disposal;
  manage water resources to achieve the proper balance between the needs of the environment and those of abstractors and other water users;
- secure, with others, the remediation of contaminated land;
- improve and develop salmon and freshwater fisheries;
- conserve and enhance inland and coastal waters and their use for recreation;
- maintain and improve non-marine navigation;
- develop a better informed public through open debate, the provision of soundly based information and rigorous research; set priorities and propose solutions that do not impose excessive costs on society.

Natural Environment Research Council (NERC)

The Natural Environment Research Council (NERC) is one of the seven UK Research Councils which fund and manage research in the UK. NERC is the leading body in the UK for research, survey, monitoring and training in the environmental sciences. NERC supports research and training in universities and in its own Centres, Surveys and Units.

The mission of the NERC is to:

- promote and support, by any means, high quality basic, strategic and applied research, survey, long-term environmental monitoring and related postgraduate training in terrestrial, marine and freshwater biology and earth, atmospheric, hydrological, oceanographic and polar sciences and earth observation;
  advance knowledge and technology, and to provide services and trained scientists and engineers which meet the needs of users and beneficiaries (including the agricultural, construction, fishing, forestry, hydrocarbons, minerals, process, remote sensing, water and other industries), thereby contributing to the economic competitiveness of the UK, the effectiveness of public services and policy and the quality of life;

to provide advice on, disseminate knowledge and promote public understanding of the fields aforesaid.

In addition to sponsoring ECN Freshwater Sites, NERC sponsors ECN Terrestrial Sites and co-ordinates and manages ECN on behalf of the sponsoring organisations.

Scottish Environment Protection Agency (SEPA)

SEPA is the body responsible for the protection of the environment in Scotland, including the islands of Shetland, Orkney and the Western Isles.

SEPA's task is to protect the land, the air and the water. It does so in partnership with others and in a way which enables Scotland to sustain a strong and diverse economy.

The Agency works towards sustainable d`evelopment through seven objectives:

- an integrated approach to environment protection and enhancement, taking into consideration the impact of all activities and natural resources;
  delivery of environmental goals without imposing disproportionate costs on industry or society as a whole;
  clear and effective procedures for serving its customers, including the development of single points of contact with the Agency;
  high professional standards, using the best possible information and analytical methods;
  organisation of its own activities to reflect good environmental and management practice, and provision of value for money for those who pay its charges, as well as for taxpayers as a whole;
  provision of clear and readily accessible advice and information on its work;
  development of a close and responsive relationship with the public, including local authorities, other representatives of local communities and regulated organisations.

This is the second volume of Protocols relating to ECN, the UK's long-term environmental monitoring programme. It explains the need for and background to the programme and provides details of the Standard Operating Procedures used at the Freshwater Sites in the network. It also specifies the systems used for data recording, data transmission, database management and quality assurance.

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