REPORT ON THE ENVIRONMENTAL ASPECTS OF THE NITRATES DIRECTIVE IN NORTHERN IRELAND

By

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EXECUTIVE SUMMARY AND CONCLUSIONS

The purpose of this Report is to inform the Department of the Environment (DOE) and the Department of Agriculture and Rural Development (DARD) to enable them to fulfil their obligations under the EC Nitrates Directive (91/676/EEC). In particular, the Report summarises the scientific knowledge concerning the extent to which groundwaters and surface waters in Northern Ireland contain elevated nitrate levels within the meaning of the Directive (i.e., in excess of 50 mg NO_3 / L), and the status of waters in Northern Ireland with respect to eutrophication.

This report is a consensus view of a DOE and DARD joint working party and reflects the information available up to 30 June 2002.

The Nitrates Directive seeks to reduce or prevent the pollution of water caused by the application of inorganic fertiliser and manure on farmland. It is designed both to safeguard drinking water supplies and to prevent wider ecological damage in the form of the eutrophication of surface waters generally.

Under the Directive Member States must monitor surface waters and groundwaters for nitrate pollution against a maximum limit of 50 mg NO_3 / L. Where this level of pollution is reached, or trends indicate that it is expected to be, land draining into the affected waters must be designated as a Nitrate Vulnerable Zone (NVZ). Three small NVZs were designated in Northern Ireland in 1999 where the concentration of nitrate in groundwaters exceeded 50 mg NO_3 / L. The European Commission is currently taking legal action against the UK (including Northern Ireland) under Article 228 of the EC Treaty for failing to comply with the judgement of the European Court of Justice (ECJ) in Case C-69/99 which declared that the UK had failed to properly and comprehensively identify groundwaters and surface waters actually and potentially containing nitrate concentrations in excess of 50 mg NO_3 / L; and to designate lands draining into such waters as Nitrate Vulnerable Zones. If sufficient action is not taken by the UK (including Northern Ireland) to ensure full compliance with the Directive, substantial fines could be imposed on the UK (including Northern Ireland) in early 2003.

The Nitrates Directive also applies to waters found to be eutrophic or which may become eutrophic where agriculture is a significant source of the nitrates present. Until a recent decision of the ECJ, the definition of eutrophication in the Directive was considered to refer only to marine waters where eutrophication is caused by excessive amounts of nitrogen. In freshwaters eutrophication has been considered to be caused by high inputs of phosphorus rather than of nitrogen. Based on this distinction it had been assumed that the provisions of the Directive to control nitrate losses from agriculture did not extend to eutrophic freshwaters.

The European Commission disagrees with this narrow interpretation and, among other things, has argued that nitrogen limitation of algae can occur in freshwaters, and therefore nitrate inputs cannot be ignored where lakes and rivers are eutrophic. In a recent judgement given in Case C-258/00 *Commission v France* the ECJ accepted the Commission's opinion. The ECJ made clear that NVZs must be declared for those freshwaters that are eutrophic and where a significant proportion of the nitrate inputs comes from agriculture.

Given the infraction proceedings currently pending against the UK (including Northern Ireland) and the clarity of the ECJ's ruling concerning eutrophic waters, the DOE and DARD jointly commissioned an extensive analysis of water monitoring data with a prioritised timetable set to address high groundwater results and eutrophication of surface waters.

The following paragraphs summarise the conclusions of the joint working party.

Conclusion 1: Compliance of Groundwaters. In addition to the existing NVZs in Northern Ireland, a further five groundwater sites have been identified as having elevated nitrate concentrations in the period 2000-2001. DOE have commissioned the Geological Survey of Northern Ireland (GSNI) to carry out further investigations to determine whether any of the five sites meet the criteria for designation as NVZs and to determine the area of land draining to these waters.

Conclusion 2: Compliance of Surface Freshwaters Used or Intended for the Abstraction of Drinking Water. It is considered that assessment of surface freshwaters against the mandatory standard of 50 mg NO_3 / L currently provides no basis for the designation of NVZs in Northern Ireland. However, assessment of surface freshwaters against the guide standard of 25 mg NO_3 / L does highlight a number of rivers where further assessment of trends in nitrate levels will be carried out.

Conclusion 3: Trophic Status of Lakes. Lough Neagh and Lough Erne are hypertrophic and eutrophic respectively. Lough Melvin and a large number of small lakes throughout Northern Ireland are also showing evidence of eutrophication or of deterioration to a eutrophic status. The role of nitrate in supporting eutrophication of these lakes cannot be ruled out. However, phosphorus is generally the nutrient limiting maximum algal production in these lake systems, and effective measures taken to control eutrophication must lower phosphorus inputs.

Conclusion 4: Trophic Status of Rivers. Macrophyte classifications suggest that the plant communities in the majority of rivers in Northern Ireland are representative of trophic status typical of “already enriched”, or “likely to become enriched” waters. Concentrations of phosphate measured in the rivers are consistent with this assessment.

Conclusion 5: Trophic Status of Marine Waters. The open coastal waters around Northern Ireland are not considered to have a eutrophication problem but eutrophic conditions have been found in Inner Belfast Lough, the tidal Lagan and the Quoile Pondage. The major sources of nitrogen to Inner Belfast Lough and the tidal Lagan are from industry and waste water treatment works. Therefore these areas have been designated under the Urban Waste Water Treatment Directive. However it may be that the whole Lagan catchment will merit designation as a NVZ if agriculture is found to be a significant (>20%) source of nitrate. At present the sources of nitrate to the Quoile Pondage are being evaluated and, if the agricultural component is found to be significant, the Quoile catchment will also merit a NVZ designation to protect water quality. Further investigations of trophic status and nitrate sources are also required for a number of other areas: Lough Foyle, Strangford Lough and the estuaries of the Newry River and Lower Bann.

Conclusion 6: Nitrate Sources. Agriculture is the most significant source of nitrate in both Lough Neagh and Lough Erne contributing 75% and 92% of the total nitrate loading respectively. While the Nitrates Directive would mandate the control of nitrate in these catchments, there is likely to be little improvement in the eutrophic status of these waters unless phosphorus losses to water are controlled simultaneously.

Conclusion 7: Manure Application Rates within NVZs. Further assessment should be carried out to examine whether a case can be made to the European Commission to justify permitting higher manure nitrogen application rates than the specified amount of 170 kg N / ha / yr in NVZs in Northern Ireland. This may be permissible under Annex III, Section 2b of the Directive, which refers to exceptions for soils with an ‘exceptionally high denitrification potential'. This option, however, will have to be viewed in context with other national and international obligations on emissions to air.

OVERVIEW

1. The impact of the Nitrates Directive (91/676/EEC) was reviewed with respect to the groundwaters and surface waters of Northern Ireland. Particular attention was paid to the issue of eutrophication.

Legal obligations under the Nitrates Directive

2. The Nitrates Directive defines three situations where agricultural nitrate pollution must be controlled; namely:

(a) Surface waters that exceed or are likely to exceed concentrations of 50 mg NO_3 / L.
(b) Groundwaters that exceed or are likely to exceed concentrations of 50 mg NO_3 / L.

In effect, the Directive extends the mandatory limit set by the Surface Waters Directive (75/440/EEC) to all surface and groundwaters so that nitrate concentrations must be less than the 50 mg NO_3 /L standard set by the World Health Organisation. This is the mandatory standard. In addition a guide standard for surface waters is operational under the Nitrates Directive where 90% of samples should be less than 25 mg NO_3 / L. Waters that exceed or are likely to exceed the mandatory standard for nitrate concentration must be identified under the Directive and land draining into those waters must be designated as NVZs.

(c) Waters that are, or are likely to become eutrophic.

The Nitrates Directive defines eutrophication as "the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned." Until recently it was considered that the definition of eutrophication contained in the Directive only applied to the sea where eutrophication is caused by excessive amounts of nitrogen. In freshwaters, eutrophication has been considered to be caused by phosphorus rather than nitrogen compounds. Based on this distinction it had been assumed that the provisions of the Directive to control nitrate losses from agricultural land did not extend to eutrophic freshwaters. The European

Commission has disagreed with this narrow interpretation and has argued that as nitrogen limitation of algae can occur in freshwaters, nitrate inputs may not be ignored where lakes and rivers are eutrophic. In a recent case brought by the Commission against France, the European Court of Justice accepted the Commission's argument. As a result, Member States are required to identify marine and freshwaters that are, or might become eutrophic where a significant proportion of the nitrate input comes from agriculture. Member States are then required to designate as NVZs all land draining into such waters which contribute to pollution.

Compliance with mandatory standard for groundwater and surface water

3. For groundwaters, previous assessments showed that the mandatory standard was being exceeded at two small areas of Northern Ireland leading to the designation of three Nitrate Vulnerable Zones (NVZs) in 1999.
4. In addition to the existing NVZs in Northern Ireland, a further five groundwater sites have been identified as having elevated nitrate concentrations in the period 2000-2001 . DOE have commissioned the Geological Survey of Northern Ireland (GSNI) to carry out further investigations to determine whether any of the five sites meet the criteria for designation as NVZs and to determine the area of land draining to these waters.
5. Only one small river is in breach of the mandatory 50 mg NO_3 / L standard, and this can be attributed to a WWTW discharge.
6. The guide standard is approached or exceeded in a number of rivers in Northern Ireland. Of the major rivers flowing into Lough Neagh, only the Upper Bann River has exceeded the nitrate guide standard and then only in 1990 and 1996. These high concentrations were strongly influenced by antecedent climatic conditions and may be permissible under the exceptions outlined in the Nitrates Directive.
7. Concentrations of nitrate in Lough Neagh and Lough Erne are low reflecting modest nitrate concentrations in the in-flowing rivers and uptake of nitrate by algae.
8. With respect to the WHO limits, nitrate concentrations in both surface and ground-waters of Northern Ireland are therefore generally low and only limited areas are impacted by high concentrations.

Trophic status of freshwaters

9. Based on chlorophyll *a* and phosphorus concentrations, and using the OECD classification system, lakes can be classed as either oligotrophic (nutrient poor), mesotrophic (moderately enriched) or eutrophic (enriched). The boundary hypertrophic category is an extreme case of eutrophy.
10. Using this classification, Lough Neagh is hypertrophic and Upper and Lower Lough Erne range from hypertrophic to eutrophic. Algal levels in the Erne system were lowered in 2001 due to the introduction of the zebra mussel.
11. Loughs MacNean and Melvin were assessed as mesotrophic in 1990, but there is evidence from sampling in 2001 that Lough Melvin is now eutrophic. A survey of all lowland lakes in the size range 1-50 ha, found that 70% had high phosphorus concentrations typical of eutrophic or hypertrophic conditions.
12. For rivers, an assessment of the trophic classification, based on aquatic plants, found very few rivers in Northern Ireland that were not enriched and these were in remote areas.
13. It can be concluded that eutrophication of freshwaters is commonplace throughout Northern Ireland.
14. With respect to the role of phosphorus vs nitrate in freshwater eutrophication, there is strong scientific evidence that the algal maximum that occurs in Lough Neagh during June is limited by phosphorus and is not influenced by nitrate inputs. However, low and growth limiting concentrations of nitrate occur in Lough Neagh during July and August, so that some degree of nitrogen limitation probably occurs. A similar situation exists in Upper Lough Erne and the shallow areas of Lower Lough Erne.

Trophic status of marine and estuarine waters

15. Open coastal waters around Northern Ireland are not considered to be eutrophic with nitrate concentrations in the western Irish Sea below internationally agreed limits for marine eutrophication.
16. With respect to the estuarine waters and the sea loughs of Northern Ireland, inner Belfast Lough, the tidal reaches of the Lagan and the Quoile Pondage are known to be eutrophic. Inner Belfast Lough and the tidal Lagan receive large nitrogen inputs from waste water treatment plants and/or industrial sources and are already designated under the Urban Waste Water Treatment Directive (91/271/EEC). If agriculture is found to be a significant nitrate source within the respective

catchments, these may merit designation as NVZs under the Nitrates Directive. An assessment of nitrate sources within the Quoile catchment is currently underway.

17. Inner Lough Foyle, the northern end of Strangford Lough and the estuarine portions of the Newry and Lower Bann Rivers are considered to require further investigation of trophic status and the contribution of agriculture to nitrate loadings.

Role of agriculture

18. Based on river monitoring, nitrate budgets and sources were assessed for Lough Neagh and Lough Erne.
19. Lowland agriculture was the major source of nitrate accounting for 75% of nitrate inputs to Lough Neagh and 92% of inputs to the rivers of the Erne catchment.
20. Towns accounted for less than 10% of the nitrate inputs. The low proportion reflects the small amounts of nitrogen excreted by humans and, in the Erne catchment, low urban populations. Nitrate loss rates from upland areas are exceptionally low leaving lowland agriculture the principal nitrate source.
21. A study undertaken at the Agricultural Research Institute of Northern Ireland found a strong linear correlation between nitrogen fertiliser inputs to grassland and losses of nitrate in drainflow. On average 13.5% of fertiliser nitrogen was lost as nitrate in drainflow. This relationship was used to estimate losses of nitrate from crops and grass.
22. In the Lough Neagh catchment, the nitrate load from agriculture estimated by difference with the other sources was very close to the load predicted from the use of nitrogen by agriculture in the catchment.
23. Nitrate inputs to the Lough Neagh rivers have increased by 72% since 1971. The increase of 2893 tonnes N is in close agreement with the increase of 2780 tonnes N predicted from the greater use of nitrogen by agriculture. By comparison, the increased annual nitrate loading from waste water treatment works was 26 tonnes N.
24. Measured nitrate loss rates in the Erne catchment were lower than predicted from the use of nitrogen by agriculture. This reflects high losses of nitrogen to the atmosphere through denitrification in soils with impeded drainage, which in turn lower the amounts of nitrate lost to drainage. Modelled rates of denitrification in Northern Ireland showed that denitrification losses were highest in the west.

25. The importance of phosphorus as the major driver of eutrophication is evident in lakes such as Upper Lough Erne, which is hypertrophic despite low nitrate inputs. From this it may be concluded that measures to control eutrophication through limiting manure applications of nitrogen are likely to be ineffective except where they lead to associated reductions in phosphorus losses to water.

26. The area of land covered by the Lough Neagh, Lough Erne and Quoile catchments accounts for some 46% of the land area of Northern Ireland. Inclusion of other possible problem areas, as defined by their eutrophic status and highlighted in the report, could bring this figure to 77% of the land area.

27. As Northern Ireland shares a land border with another Member State, the Republic of Ireland (RoI), it is required by the Nitrates Directive and also the Water Framework Directive (2000/60/EEC) to co-ordinate its approach to the management of shared waters with the RoI. This will require assessment of the nutrient inputs to these shared waters.

28. The Nitrates Directive lists options for granting exemptions from the requirements to limit the quantities of manure applications. Some of the stated grounds seem relevant to Northern Ireland, e.g. high denitrification losses, high rainfall and a prolonged growing season. These may provide opportunities to alleviate the more restrictive aspects of the Directive, especially if they are accompanied by credible measures to lower phosphorus losses from agriculture.

NOTES ON UNITS

The terminology for expressing nitrogen and nitrate concentrations is confusing. Scientists express nitrate by the amount of nitrogen it contains, expressing concentrations as mg N / L or, in the case of marine science as, moles / L. The Nitrates Directive uses the unit mg NO_3 / L, which includes three oxygen atoms and so gives larger numbers than mg N / L. Thus the 50 mg NO_3 / L nitrate limit in the legislation is the same as 11.3 mg N / L. In this document concentrations are expressed as mg NO_3 / L.

When referring to the use of nitrogen by agriculture, the Directive expresses inputs by units of nitrogen, for example kilogram (kg) of nitrogen, which is the unit used in this paper in partitioning the sources of nitrate in catchments.

GLOSSARY AND ABBREVIATIONS

AESD – Agricultural and Environmental Science Division, DARD.
Aesthetic impact – Assessment of effect upon appearance.
Algae – General term applied to photosynthetic organisms that are generally aquatic, may be microscopic or very large (e.g. seaweed), and may be floating or attached.
Aquatic – Associated with water, possibly growing or living in water.
ARINI – The Agricultural Research Institute for Northern Ireland.
Biodiversity – (Biological Diversity)-the variety of life, as indicated by the number of species present.
Catchment – The area of land drained by a river or river system (see river basin).
Chlorophyll *a* – The major photosynthetic pigment of most algae and plants.
DARD – Department of Agriculture and Rural Development.
Denitrification – the microbial reduction of nitrogenous oxides, nitrate and nitrite. The principal products are di-nitrogen (N_2) and nitrous oxide (N_2O), though nitric oxide (NO) has occasionally been detected. These gases are lost to the atmosphere where nitrous oxide may be contributing to global warming as it is a greenhouse gas.
Diffuse pollution – Pollution that does not arise from an easily identifiable source (such as an effluent discharge pipe). Usually refers to run-off or leaching from land.
Dissolved oxygen – The amount of oxygen dissolved in water. Oxygen is vital for aquatic life, so this measurement is a test of the health of a water body and can be used to grade water quality.
DoE – Department of the Environment.
DRD – Department for Regional Development.

EC – European Community. (Despite the creation of the European Union under the Maastricht Treaty, the term European Community continues to be used).

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

- **EC Surface Water Directive** - Council Directive concerning the quality of surface water intended for the abstraction of drinking water in the Member States (75/440/EEC).
- **EC Drinking Water Directive** – Council Directive relating to the quality of water intended for human consumption (80/778/EEC).
- **EC Nitrates Directive** – Council Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC).
- **EC Urban Waste Water Treatment (UWWT) Directive** – Council Directive concerning urban waste water treatment (91/271/EEC).
- **EC Water Framework Directive** – Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy.

ECJ – European Court of Justice.

Ecology –The branch of biology dealing with the relation of organisms to one another and to their physical surroundings.

EHS – Environment and Heritage Service, an Executive Agency within DOE.

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

Habitat – The natural home of an organism.

Hydrogeology – The study and investigation of water below ground.

Hypertrophic – A description of water, which is extremely nutrient-enriched and affected by heavy growths of algae and/or other water plants.

Leaching - Removal of soluble substances by the action of water percolating through soil, waste or rock.

Limiting nutrient – The nutrient in an ecosystem that is in shortest supply relative to demand and can thus restrict plant production.

mg – Milligram (equivalent to one-thousandth of a gram).

mg / L – Milligram per litre.

Macrophytes – Large plants, including all higher water plants, together with some algal species that can be identified by the naked eye.

Mesotrophic – A description of water which is of medium nutrient status and medium biological productivity.

Methaemoglobinaemia – An uncommon disease condition caused by the decreased ability of blood to carry vital oxygen around the body. A frequent cause of methaemoglobinaemia is nitrate in drinking water. Infants are most often affected, and may show signs of blueness around the mouth, hands and feet, hence the common name “blue baby syndrome”. In extreme cases the disease can be fatal.

MRP – Molybdate reactive phosphorus as measured according to the method of Murphy & Riley (1962). See also SRP.

N – Nitrogen.

Nitrate Vulnerable Zone (NVZ) – An area where nitrate concentrations exceed, or are at risk of exceeding the limits laid down in the EC Nitrates Directive, or where they contribute to the enrichment of surface waters. Within NVZs, compulsory, uncompensated agricultural measures can be introduced as a means of reducing those levels.

NO_3 – Nitrate.

Nutrient – A substance which provides nourishment for living organisms.

Nutrient enrichment – The oversupply of nutrients to an ecosystem (see Eutrophic).

OECD – Organisation for Economic Co-operation & Development.

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

OSPAR – Oslo and Paris Commission established to administer the Oslo and Paris Conventions for the prevention of marine pollution.

P – Phosphorus.

Phosphate – Salt of phosphoric acid. A substance, which provides nourishment for living organisms and is often used as a fertiliser.

Phytoplankton – Community of largely microscopic algae floating or suspended in waters.

Point source pollution – Pollution that arises from an easily identifiable source, usually an effluent discharge pipe.

River basin –The area of land drained by a river system (see catchment).

Saline – Elevated above freshwater salt concentrations.

Scum – The surface debris that can result from blooms of algae and the break up of other plants.

Secchi disc – A measure of water clarity in metres.

Sediment – Matter settling to the bottom of a water body.

Sensitive Area (eutrophic) – Area designated under the UWWT Directive either because it is already affected by eutrophication or because it is at risk of being so affected.

Septic tank – A tank in which the organic matter in sewage is disintegrated through bacterial activity.

SRP – Molybdate reactive phosphorus as measured on filtered water samples according to the method of Murphy and Riley (1962). Although not precisely equivalent to soluble phosphates, SRP is for practical purposes a good measure of the amount of soluble phosphate in water.

Synoptic – A snapshot overview.

Total phosphorus (TP) – The sum of soluble and insoluble phosphorus fractions.

Transparency – The degree to which light can pass through water.

Trophic status – The category of a water in relation to the process of eutrophication.

***u*g** – Microgram (equivalent to one-millionth of a gram).

***u*g P / L** –Microgram of phosphorus per litre or parts per billion.

UWWT Directive – Urban Waste Water Treatment Directive.

WHO - World Health Organisation.

WWTW - Waste water treatment works.

1 INTRODUCTION

1.1 Overview of the Nitrates Directive

The Nitrates Directive defines three situations where nitrate losses from agricultural land should be controlled. The first two relate to public health issues impacted by nitrate and are based in particular on the recommendations of the World Health Organisation (WHO) as a safeguard against methaemoglobinaemia. In practice the limits placed by the Nitrates Directive on nitrate concentrations are those set by the EC Surface Water Directive (75/440/EEC) and the EC Drinking Water Directive (80/778/EEC) for potable water sources and supplies respectively. The criteria for identifying waters as polluted are detailed in Annex I of the Nitrates Directive as follows:

1. Groundwaters containing more than 50 mg NO_3 / L or which could contain more than 50 mg NO_3 / L if action pursuant to Article 5 of the Nitrates Directive is not taken ;
2. Surface freshwaters, in particular those used or intended for the abstraction of drinking water which contain or could contain, more than the concentration of nitrates laid down in the Surface Water Directive if action pursuant to Article 5 is not taken; and
3. Natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters found to be eutrophic or in the near future may become eutrophic if action pursuant to Article 5 is not taken.

The mandatory standard set by the Surface Water Directive is that 95% of samples should be less than 50 mg NO_3 / L. The Surface Water Directive also sets a guide or G standard, which is that 90% of samples should be less than 25 mg NO_3 / L. These concentrations are also the maximum admissible concentration of 50 mg NO_3 / L and the guide level of 25 mg NO_3 / L laid down in the Drinking Water Directive. Member States should endeavour to respect the G values. There are a number of exemptions to the standards if the excess concentrations result from floods or other exceptional events or when the concentrations occur sporadically rather than in a series.

1.2 Current application of the mandatory standard in Northern Ireland

In the context of elevated nitrate levels, three NVZs were designated under the Nitrates Directive in Northern Ireland in 1999 where the concentration of nitrate in groundwaters exceeded 50 mg NO_3 / L. Two of the NVZs (11.5 km^2 and 0.5 km^2 respectively in extent) are in the Comber area of Co Down. The third (3.8 km^2) is near Clogh Mills, Co Antrim. Action Programmes became compulsory in the three NVZs in June 1999.

1.3 European Court of Justice ruling on the application of the Nitrates Directive to eutrophic waters

A recent decision of the European Court of Justice (ECJ) in response to an action brought by the European Commission against France (Case C-258/00)[1] has caused the re-appraisal of the role of nitrates in the eutrophication of surface waters of Northern Ireland. The French Government had argued that, in freshwaters where eutrophication is normally considered to be limited by phosphorus rather than nitrogen, the agricultural land draining into the waters in question need not be identified as NVZs. The Advocate General's Opinion (issued November 2001) supported the Commission's viewpoint that nitrogen as a nutrient was always an important factor in the eutrophication of surface waters and could not be so disregarded in controlling eutrophication which is an objective of the Nitrates Directive.

The Commission's justification is that:

1 algae and higher plants require both nitrogen and phosphorus;
2 there are documented instances where nitrogen limitation has been observed in freshwater bodies; and
3 evidence from experimental studies where additions of both nitrogen and phosphorus to lakes or lake water were required to increase levels of algal productivity.

Additionally, the Advocate General accepted the viewpoint of the Commission that permitting elevated amounts of nitrate to enter the sea via the freshwater catchment could potentially have adverse environmental impacts in the marine environment and should therefore be controlled by the Directive.

In June 2002 the ECJ also ruled that the Nitrates Directive places an obligation on Member States to designate the catchments of eutrophic waters as NVZs where agriculture is a significant source of nitrate pollution. Discussions with officials from the European Commission indicated that NVZs should be designated where the eutrophic condition of a water body has been established and agriculture can be shown to contribute more than 20% of the overall nitrate loading to those waters.

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[1] It should be noted that it proved impossible to obtain the papers relating to the French position. The French argument referred to is therefore as reported in the ECJ Proceedings Case C-258/00, Opinion of the Advocate General, LA Geelhoed, 29 November 2001 and the Judgement of the Court, 27 June 2002.

1.4 The need for scientific analysis concerning nitrate pollution in Northern Ireland

The European Commission is currently taking legal action against the UK (including Northern Ireland) under Article 228 of the EC Treaty for failing to comply with the previous judgement of the ECJ in Case C-69/99. This Case stated that the UK had failed to properly and comprehensively identify groundwaters and surface freshwaters affected by concentrations of nitrates in excess of the mandatory standard of 50 mg NO_3 / L laid down by the Nitrates Directive, and to designate land draining into those waters as Nitrate Vulnerable Zones. If sufficient action is not taken by the UK (including Northern Ireland) to ensure full compliance with this aspect of the Directive, substantial fines could be imposed on the UK (including Northern Ireland) in early 2003. DOE had therefore undertaken to carry out an extensive analysis of water monitoring data with a prioritised timetable set to address high groundwater results.

In addition, the Advocate General's Opinion on the *Commission v France* (issued in November 2001), also indicated that the obligations laid down in the Directive concerning eutrophic waters could potentially be considerably wider than previously understood. Pending the ECJ's judgement on this case, the DOE also undertook to commission an analysis of the status of waters in Northern Ireland in relation to eutrophication, pollution by nitrate and the interaction of nitrate and phosphorus in eutrophication of these waters. As already stated, the ECJ's judgement in *Commission v France* (published in June 2002) upheld the approach taken by the Advocate General.

1.5 Scope of this report

This report reviews the impact of the Nitrates Directive with respect to the surface and groundwaters of Northern Ireland and is a consensus view of a DARD and DOE joint working party. More specifically, it summarises scientific knowledge of the status of waters in Northern Ireland in relation to compliance with the mandatory standard for nitrate pollution (i.e., 50 mg NO_3 / L); and eutrophication, pollution by nitrate and the interaction of nitrate and phosphorus in eutrophication of these waters. Following analysis of this data, a decision will be taken on the need for any further NVZ designations in Northern Ireland.

DARD and EHS scientists have gathered a considerable body of data over the last thirty years. In relation to freshwaters, DARD has collected data in support of scientific studies on the eutrophication of Lough Neagh and Lough Erne, while the EHS data are from statutory monitoring of groundwaters, rivers, and lakes throughout Northern Ireland. In areas where the two data sources are complementary, they have been found to be mutually consistent. The quality of the data from the long-term sampling of the rivers and large lakes combined with large-scale surveys of small lakes gives authority to statements about the current state of the freshwater environment. Detailed studies on the nitrogen cycle carried out by AESD on experimental plots provide a scientific basis for defining the relationship between nitrogen inputs to grassland and losses of nitrate in agricultural drainage.

The European Commission has produced a situation report on the Implementation of the EC Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) across Member States (EC, 2002). In this report it is recorded that the Commission's view is that the Lower Bann Estuary, Carlingford Lough, Belfast Lough and Lough Foyle should have been designated as being sensitive to nutrient enrichment. On behalf of EHS, AESD has in recent years undertaken assessment of the trophic status and nutrient budgets of all the sea loughs in Northern Ireland. In addition, AESD maintains a sampling programme on the Irish Sea. A summary is presented here on the eutrophication of the marine waters of Northern Ireland. In the marine environment the predominant role of nitrate as the driver of eutrophication is not in doubt.

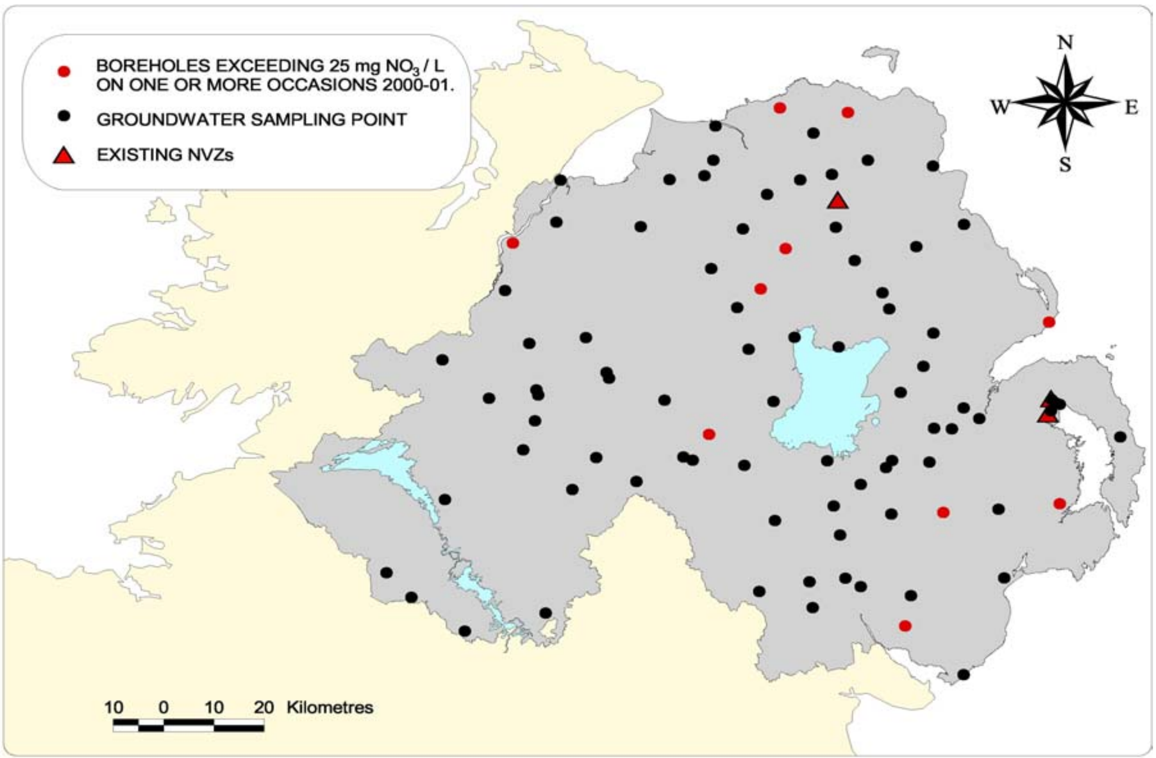
2 COMPLIANCE OF GROUNDWATERS AND SURFACE WATERS IN NORTHERN IRELAND WITH THE NITRATES DIRECTIVE

2.1 Groundwater

An assessment of groundwater quality data collected during 1992 to 1994 indicated that two relatively small areas of groundwater should be identified as polluted under the Nitrates Directive in Northern Ireland (Robins *et al.*, 1994). These were in a sand/gravel aquifer at Clogh Mills, Co Antrim and in the Permo-Triassic sandstone near Comber, Co Down. Subsequently, three NVZs were designated, one at Clogh Mills and two near Comber (Southern Science, 1996 a & b).

Nitrate data from the EHS regional groundwater quality monitoring network for the period 2000 to 2001 has recently been analysed. The network was finalised in 2000 and comprises approximately 80 sites (Fig 2.1), most of which are private agricultural boreholes.

Figure 2.1 EHS regional groundwater quality monitoring network. Map shows boreholes that exceeded 25 mg NO_3 / L on one or more occasions in 2000-01 and boreholes within existing NVZs.



Outside existing NVZs the monitoring data shows no overall pattern to the distribution of high nitrates. The widespread occurrence of clay till deposits and impeded drainage soils is considered to limit impact on groundwater generally and this is supported by a survey carried out by British Geological Survey in the early 1990's and by the more recent EHS monitoring. Nevertheless there are widespread, very localised situations where groundwater is vulnerable to point source and diffuse source agricultural pollution.

The assessment of the 2000-2001 data identified 10 groundwater sites where nitrate was detected above 25 mg NO_3 / L on one or more of six sample rounds (Fig 2.1). Five out of the 10 groundwater sites had either:

- mean nitrate levels greater than 50 mg NO_3 / L; or
- maximum nitrate levels greater than 50 mg NO_3 / L; or
- mean nitrate levels between 40 - 50 mg NO_3 / L.

Further groundwater sampling has been carried out around each of the five sites, together with an examination of other geological and hydrogeological data (GSNI, 2002 a & b). Based on an assessment of this additional data it will be decided if the areas of land draining to these five waters meet the criteria for designation as NVZs.

Conclusion 1: Compliance of Groundwaters. In addition to the existing NVZs in Northern Ireland, a further five groundwater sites have been identified as having elevated nitrate concentrations in the period 2000-2001. DOE have commissioned the Geological Survey of Northern Ireland (GSNI) to carry out further investigations to determine whether any of the five sites meet the criteria for designation as NVZs and to determine the area of land draining to these waters.

2.2 Surface freshwaters

2.2.1 Compliance at public surface water supply abstraction points

Nitrate monitoring is carried out at 53 surface public drinking water supply abstraction points in Northern Ireland. Results of monitoring carried out at these sites by Water Service (DRD) over the period 1996 to 2000 show compliance with the mandatory and guideline nitrate standards under the Surface Water Directive.

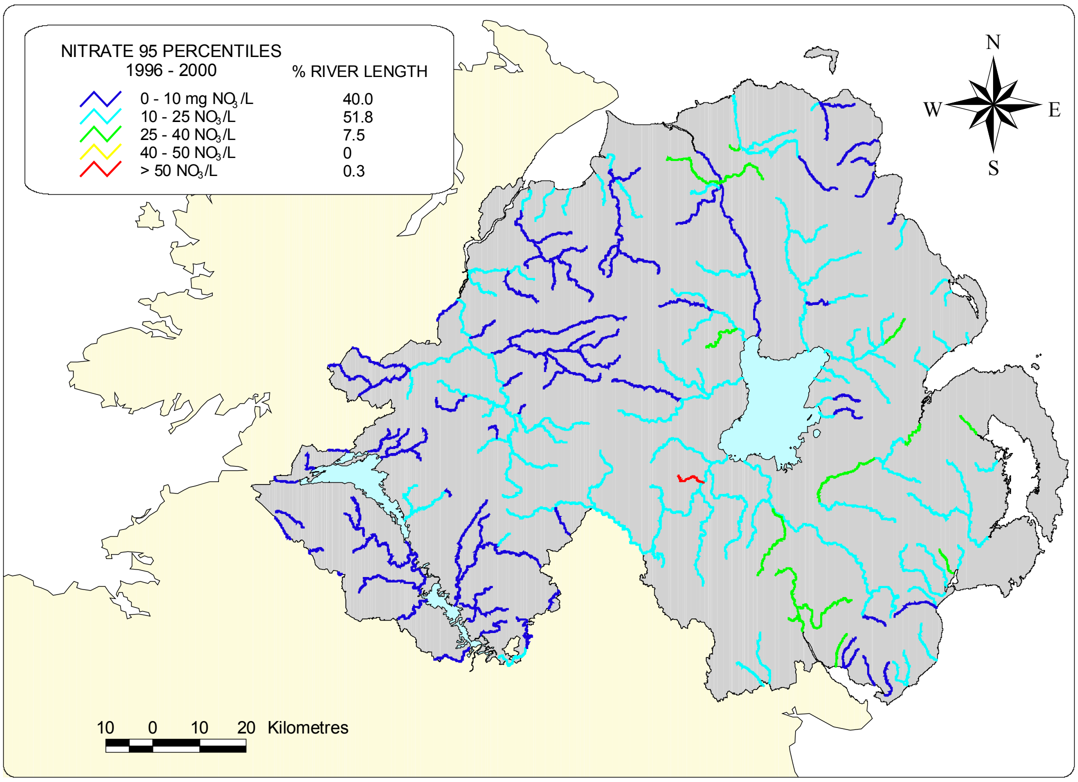
2.2.2 Compliance of rivers

EHS carries out statutory monitoring at the most downstream freshwater sampling site in all 49 substantive river catchments (those with a flow of at least 1 million gallons per day) for compliance with the Nitrates Directive. These sites are sampled monthly and, in order to ensure a robust and relatively stable assessment, free from year to year fluctuations in water quality, a combined five-year dataset from 1996 to 2000 was analysed. A parametric method was applied whereby a 95-percentile was calculated from the five year dataset, around which 90% confidence intervals were constructed. If both the 95-percentile and the lower confidence interval exceeded 50 mg NO_3 / L, the sample point was adjudged to have failed the requirements of the Directive. This means that it is 95% certain that a sample point has exceeded 50 mg NO_3 / L. Using this statistical test, all 49 sites complied with the mandatory standard over the period 1996 to 2000.

In addition, since the early 1990s, a further 213 river sites have been monitored by EHS for nitrate on a monthly basis. Analysis of data at all of the 262 sites over the period 1996-2000 shows that all but one of the rivers in Northern Ireland complied with the Surface Water Directive mandatory standard requiring 95% of samples[2] to be less than 50 mg NO_3 / L (Fig 2.2). Nitrate levels in some 92% of the river length were less than 50% of the mandatory 95-percentile concentration. The one instance where the mandatory standard was exceeded was in the small River Rhone, Co Tyrone. Here the natural stream flow is small and the high nitrate concentrations are most likely directly related to the discharge from Moygashel WWTW.

[2] calculated as the 95-percentile

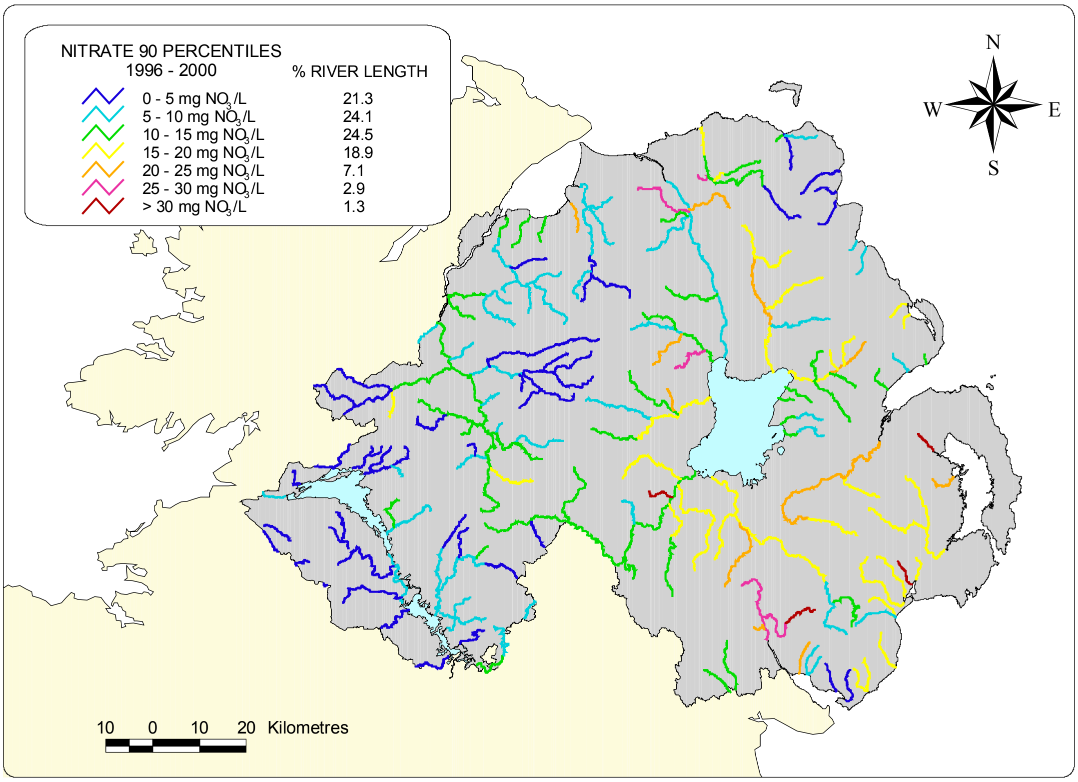
Figure 2.2 Nitrate status of rivers in Northern Ireland based on 95-percentile concentrations, 1996-2000



Compliance was also assessed against the Surface Waters Directive guide standard, that 90% of samples[3] should be less than 25 mg NO_3 / L (Fig 2.3). This analysis also showed a high level of compliance with only 4% of the river length exceeding the guide value. A further 7% of river length approached the guide value with concentrations in the range 20-25 mg NO_3 / L. These data require further trend analysis to assess the need for future action.

[3] calculated as the 90-percentile

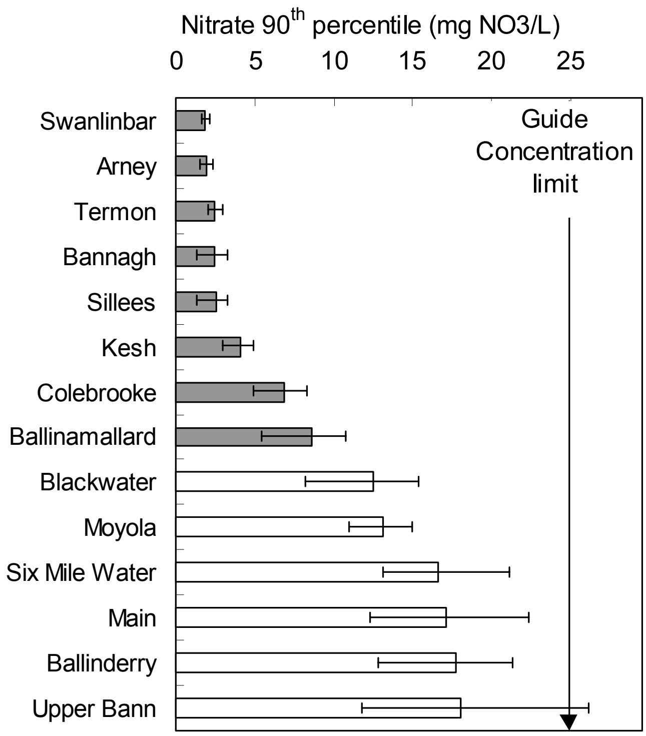
Figure 2.3 Nitrate status of rivers in Northern Ireland based on 90-percentile concentrations, 1996-2000



2.2.3 Trends in nitrate concentrations in rivers from DARD data

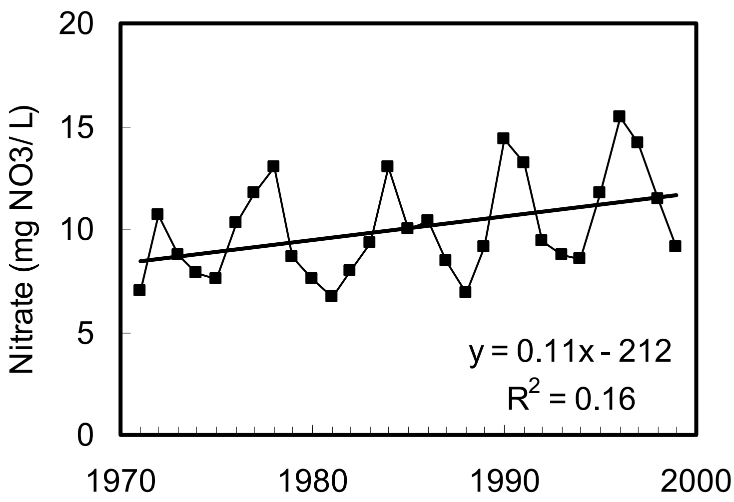
Additional data from DARD studies specifically investigating eutrophication in the Lough Neagh and Lough Erne catchments show that the Upper Bann had small and infrequent breaches of the guide standard in 1990 and 1996 out of a data run covering 30 years (Foy, 2002a). Figure 2.4 gives the 90-percentile concentrations of the rivers flowing into Lough Neagh and Lough Erne. Nitrate concentrations in the Lough Erne catchment are particularly low although they drain into a lake system that is eutrophic (Foy, 2002b).

Figure 2.4 Nitrate 90 percentile concentrations in Lough Erne Rivers (shaded) and Lough Neagh Rivers, 1994-99. Bars denote range of annual values from 1994 to 1999. Concentrations in excess of 25 mg NO_3 / L were in breach of the Guide value of the Surface Water Directive.



Long-term trend analysis of river nitrate concentrations is only possible in the rivers flowing into Lough Neagh where there is a continuous record of monitoring extending to 1970. In these rivers, nitrate concentrations show a positive correlation with time (Fig 2.5). However the cumulative increase observed over 30 years is substantially lower than the variation that occurs from year to year. Experimental investigations have shown that this short-term variation reflects climatic influences on nitrate leaching, as high leaching losses occur after dry summers (Watson *et al.,* 2000a). The peaks in nitrate concentrations have occurred quite regularly at intervals of approximately six years and this series may reflect a climatic signal in low summer rainfall detected at Armagh Observatory and extending back to 1840 (Butler *et al.*, 1998). Although this is perhaps of only academic interest, the marked climatic impact on river nitrate concentrations in Northern Ireland does suggest that it will require a very long-term monitoring programme to assess the effectiveness, in terms of lowered nitrate concentrations, of regulations operational within NVZs in Northern Ireland.

Figure 2.5 Flow weighted annual nitrate concentrations of Lough Neagh rivers. Trend line shown for regression with time.



2.2.4 Compliance of lakes

Both EHS data and data from the eutrophication studies carried out by DARD show that nitrate concentrations in Lough Neagh and Lough Erne are much lower than the 50 mg NO_3 / L standard. Not only are the concentrations of nitrate in their in-flowing rivers generally below the mandatory and guide standards, but lake nitrate concentrations are further lowered by the uptake of nitrate by algae and other plants growing in these lakes. The maximum nitrate concentration observed in Lough Neagh by DARD was 10 mg NO_3 / L in March 1990 and the maximum concentration in Lough Erne was 7 mg NO_3 / L, also in March 1990.

Conclusion 2: Compliance of Surface Freshwaters Used or Intended for the Abstraction of Drinking Water. It is considered that assessment of surface freshwaters against the mandatory standard of 50 mg NO_3 / L currently provides no basis for the designation of NVZs in Northern Ireland. However, assessment of surface freshwaters against the guide standard of 25 mg NO_3 / L does highlight a number of rivers where further assessment of trends in nitrate levels should be carried out.

3 EUTROPHICATION AND THE NITRATES DIRECTIVE IN NORTHERN IRELAND

3.1 What is eutrophication?

Eutrophication is the term used to describe the process of nutrient enrichment, where a water body changes from a nutrient poor state (oligotrophic) to a nutrient rich state (eutrophic). Given suitable growing conditions, in terms of light, water temperature, flow and other ecological pressures, the maximum amount of plant material in a given water body is dependent on the availability of nutrients, in particular nitrogen and phosphorus. The concentration of these nutrients is therefore a key factor in determining the trophic status of a water body.

There are a number of effects on water quality associated with eutrophication that are summarised below:

- health risks from contamination of drinking water supplies and recreational waters by toxic algae and algal scums;
- added costs in removal of algae from water intakes and water treatment facilities;
- loss of habitats leading to loss of species biodiversity;
- loss of fisheries;
- limits on use or added costs for industry and agriculture; and
- undesirable aesthetic impacts such as odours, loss of transparency and clogging by weeds leading to loss of amenity value.

For freshwater lakes and rivers, phosphorus has been the nutrient commonly regarded as being in shortest supply and is sometimes referred to as the 'limiting nutrient'. Algae and aquatic plants also require nitrogen for growth but freshwaters are generally considered to be over-supplied with inorganic sources of nitrogen, such as nitrate and ammonium, so that nitrogen is not in such short supply that it limits growth. Moreover, when inorganic nitrogen in lakes, predominantly nitrate, is at growth limiting concentrations, certain species of blue-green algae have the capacity to fix atmospheric nitrogen, that is di-nitrogen, which is dissolved in the water. As di-nitrogen is always available from the atmosphere, attempting to control algae by reducing nitrogen inputs is likely to lead to a switch to nitrogen-fixing blue-green algae rather than a reduction in algae. This switch can be undesirable as the nitrogen-fixing algae have a high propensity to form surface scums or algal blooms on lakes. Unlike in the freshwater environment, nitrogen is usually considered to be the limiting nutrient in the marine environment where it is in shortest supply. Alternating conditions of nitrogen and phosphorus limitation of algae may occur in estuaries, which receive nutrients both from the land and from the sea.

3.2 Nitrates Directive definition of eutrophication

The definition of eutrophication in European legislation focuses on the undesirable effects of enrichment. The Nitrates Directive defines eutrophication in Article 2(1) as

"*the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned".*

Both the UWWT and Nitrates Directives require the identification/designation of waters, which are "found to be eutrophic or which in the near future may become eutrophic if protective action is not taken". No definition of eutrophic (the state) is given. However, based on the definition of "eutrophication" (the process) given in the Directives, the UK interpretation is that waters should be identified/designated if nutrient enrichment has caused, is causing, or may cause accelerated growth of algae and plant life. Under this interpretation this accelerated growth would in turn lead to an "undesirable disturbance" to the ecology and/or water quality.

This interpretation is intended to facilitate the identification not only of waters which might be considered classically "eutrophic" (as defined by internationally recognised schemes such as the 1982 OECD[4] trophic classification for standing freshwaters), but also waters of lower trophic status which are experiencing, or may experience undesirable effects due to nutrient enrichment and accelerated growth. The UK recognises the need to protect this latter category of waters, particularly sites of high wildlife conservation interest, as these may be particularly sensitive to the effects of increased nutrient loadings.

The assessment of whether a water body is eutrophic or may become eutrophic is not possible simply by reference to absolute numeric criteria. It is necessary to consider the current condition of the water body (ideally compared to a reference condition) and whether undesirable effects due to nutrient inputs and the growth of algae or plants have occurred, and to predict whether such effects may occur if preventive action is not taken. A number of symptoms should be considered in order to come to a rounded judgement, taking into account the weight of evidence, as to whether an individual water body is suffering an "undesirable disturbance" or may do so in the absence of preventive action.

[4] For OECD classification see page 30

3.3 Trophic conditions in Northern Ireland - Lakes

3.3.1 Indicators of eutrophication in lakes

The Organisation for Economic Co-operation & Development (OECD) benchmark report of 1982 divided lakes into three trophic categories: oligotrophic (nutrient poor), mesotrophic (moderately enriched) and eutrophic (enriched) (Table 3.1). A further 'boundary category' of hypertrophic was defined as an extreme state of eutrophy. These trophic categories were then defined in terms of response and by total phosphorus concentration. Response was assessed by chlorophyll *a* concentration, which is an index of the amount of algae suspended in the water. High levels of algae, and hence high levels of chlorophyll *a*, will also lower water transparency. The Secchi disc measurement, which measures water transparency, was also used in the OECD report to assess lake response. Secchi disc has proved to be a less satisfactory index of enrichment in Irish lakes as other factors, such as pigments from peat, also lower water transparency.

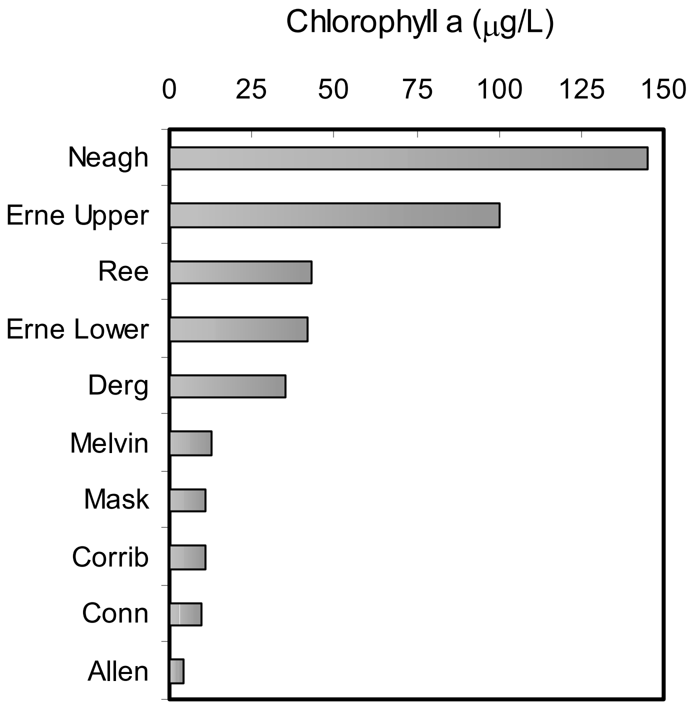
Table 3.1 OECD (1982) OECD trophic state classification and trophic designation for Lough Neagh

Trophic Category	Total Phosphorus (μg P / L)	Chlorophyll *a* (μg / L)		Secchi Disc (Metres)	
		Average	Maximum	Average	Minimum
Oligotrophic (O)	≤ 10	≤ 2.5	≤ 8	≥ 6	≥ 3
Mesotrophic (M)	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic (E)	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypertrophic (H)	≥ 100	≥ 25	≥ 75	≤ 1.5	≤ 0.7
Lough Neagh	145 (H)	59 (H)	95 (H)	1.1 (H)	0.8 (E)

3.3.2 Trophic status of Lough Neagh

The OECD classification system, based on concentrations of chlorophyll *a* and total phosphorus, places Lough Neagh firmly within the hypertrophic category (Table 3.1). Water transparency values, measured by Secchi disc, are also typical of hypertrophic–eutrophic lakes. Based on maximum chlorophyll *a* concentrations, Lough Neagh is the most eutrophic of the larger lakes in Northern Ireland and the Republic of Ireland (Fig 3.1). It should also be noted that the impact of Lough Neagh extends downstream through the Lough Beg, Lower Bann river, and Lower Bann estuary.

Figure 3.1 Maximum chlorophyll *a* concentrations from the ten largest lakes in Northern Ireland and the Republic of Ireland.



3.3.3 Nitrogen vs phosphorus limitation in Lough Neagh

Given the viewpoint of the European Commission, outlined in the Introduction, on the potential role of nitrogen in the process of freshwater eutrophication, it is necessary to assess the extent to which the case for phosphorus rather than nitrogen limitation can be made for Lough Neagh. In Lough Neagh, phosphorus concentrations are so high that phosphorus limitation of algae is no longer extreme, as algae in hypertrophic lakes are sufficiently over-supplied with nutrients that they are likely to be limited by daylight rather than availability of nutrients. Nevertheless, algal growth depletes concentrations of soluble phosphates to trace concentrations from April to June and studies by AESD show that the algal crop maximum, which occurs in June, is limited by phosphorus (Gibson & Stevens, 1979). This is supported by a statistical study that found a significant correlation between chlorophyll *a* over the period April-June in Lough Neagh and inputs of phosphates over the spring period (Stronge *et al.,* 1998). There was no corresponding association between chlorophyll *a* variation and nitrate inputs. Nitrate concentrations in Lough Neagh decline during April-June but remain above values that would arrest algal growth. These facts support the contention that it is phosphorus rather nitrogen that limits the algal crop maximum in Lough Neagh.

In July there is a release of phosphorus into the water of Lough Neagh from the lake sediments, so removing the possibility of phosphorus limitation over the second half of the year. However, in July and August, nitrate concentrations are further depleted to trace or growth limiting concentrations. At this time it is probable that algae in the Lough are limited by nitrogen. Thus, in the context of the opinion of the Commission, it is not possible to unequivocally state that nitrogen has no effect on the trophic status of Lough Neagh. In addition, there is a probable interaction between summer phosphorus and nitrate concentrations in Lough Neagh.

A study carried out by DARD on the interaction between nitrate and release of phosphorus from lake sediments showed that the presence of nitrate in lake water effectively suppressed phosphorus release (Foy, 1986). In this study, when additional nitrate was added to a small lake, it was largely lost through denitrification rather than increased algal uptake. In Lough Neagh a similar phenomenon probably exists as the timing of the summer release of phosphorus from the lake sediment coincides with the depletion of nitrate from the water column. The nitrate budget of Lough Neagh shows that large losses of nitrate occur via Lough sediments which exert a heavy demand on the nitrate supply during the summer months (Gibson *et al.* 1992). This demand is in competition with the phytoplankton in the lake and it is probably the sediments rather than the phytoplankton which control the nitrate concentration in the lake at this time. This is an issue that requires further research.

3.3.4 Trophic status of Lough Erne

Phosphorus concentrations in Upper and Lower Lough Erne have been indicative of eutrophic conditions (Table 3-2). Algal blooms have ensured maximum chlorophyll *a* concentrations that are typical of hypertrophic or eutrophic conditions (Table 3.2; Fig 3.1). A similar classification is obtained using average concentrations of chlorophyll *a*, except that, in the Broad Lough section of Lower Lough Erne, average concentrations are more typical of mesotrophic conditions. Due to the greater water depth and the high concentration of peat-stained water in this part of Lough Erne, algae tend to be light limited and chlorophyll *a* is lower than predicted from the high phosphorus concentrations in the water. When one considers the issue of nitrogen vs phosphorus limitation for the Erne system, low or trace nitrate concentrations that would limit algal growth have frequently been measured in Upper Lough Erne during the summer months. In Lower Lough Erne, trace nitrate concentrations are less commonly observed and are confined to a region of the Lough immediately downstream of Enniskillen (Foy, 2002b). Therefore, while phosphorus is likely to play the dominant role in determining the high algal populations observed in the lake, the possibility of some degree of nitrogen limitation is probable, especially in Upper Lough Erne.

Table 3.2 Trophic classification of sampling stations in Upper and Lower Lough Erne 1994 to 1999. Letters M, E and H denote mesotrophic, eutrophic and hypertrophic conditions respectively as defined by the OECD classification.

Lough	Sampling Station	Average Phosphorus (μg P / L)	Chlorophyll *a* Average (μg / L)	Chlorophyll *a* Maximum (μg / L)	Secchi Disc Average (Metres)	Secchi Disc Minimum (Metres)
Upper Lough Erne						
	Lady Craigavon Bridge	87.1 (E)	27.4 (H)	100.5 (H)	-	-
Lower Lough Erne						
	Portora	87.8 (E)	18.1 (E)	63.9 (H)	0.9 (H)	0.2 (H)
	Friars Leap	90.9 (E)	19.4 (E)	194.7 (H)	0.9 (H)	0.3 (H)
	Rossahilly	85.7 (E)	22.3 (E)	78.2 (H)	1.0 (H)	0.3 (H)
	Killadeas	76.8 (E)	17.6 (E)	79.3 (H)	1.2 (H)	0.6 (H)
	Broad Lough	63.7 (E)	5.5 (M)	41.8 (E)	2.0 (E)	0.9 (E)

3.3.5 Lough Erne and the Zebra Mussel

The assessment given above of the trophic state of the Erne pertains only to 1999. In 1995 or 1996 the zebra mussel (*Dreissena polymorpha*), which feeds by filtering and removing algae and other particulate matter from the water, was introduced to the Erne system. It has expanded throughout Upper and Lower Lough Erne and, by 2000, it was obviously reducing algal levels. This was strikingly apparent in 2001 and the water quality classifications of 2001 are summarised in Table 3.3. Total phosphorus concentrations remained typical of strongly eutrophic conditions but average and maximum chlorophyll *a* concentrations in the Lower Lough were only indicative of mesotrophic conditions. In Upper Lough Erne chlorophyll *a* had been lowered from a hypertrophic to a eutrophic classification. A secondary impact in 2001 was increased water clarity, especially in the shallow areas of Lower Lough Erne. Initial observations indicate that this may have led to greater growth of aquatic plants (macrophytes) in the shallow areas of the Lough. This shift in ecological impact is inevitable given increased water clarity and continued nutrient inputs. The macrophyte populations in Lough Erne will be the subject of future studies as a further indicator of eutrophication.

Table 3.3 Trophic classification of sampling stations in Upper and Lower Lough Erne for 2001. Letters M, E and H denote mesotrophic, eutrophic and hypertrophic conditions respectively.

Lough	Sampling Station	Average Phosphorus (µg P / L)	Chlorophyll *a* Average (µg / L)	Chlorophyll *a* Maximum (µg / L)	Secchi Disc Average (Metres)	Secchi Disc Minimum (Metres)
Upper Lough Erne						
	Lady Craigavon Bridge	78.0 (E)	12.2 (E)	29.6 (E)	-	-
Lower Lough Erne						
	Portora	77.0 (E)	4.7 (M)	23.4 (M)	1.8 (E)	0.8 (E)
	Friars Leap	78.6 (E)	4.2 (M)	15.7 (M)	1.7 (E)	0.8 (E)
	Rossahilly	80.4 (E)	7.9 (M)	10.9 (M)	1.4 (E)	0.7 (E)
	Killadeas	70.8 (E)	6.3 (M)	16.1 (M)	1.7 (E)	1.2 (E)
	Broad Lough	62.7 (E)	3.4 (M)	19.0 (M)	2.4 (E)	1.4 (E)

3.3.6 Lough Melvin and other large lakes

When the other large lakes in Northern Ireland, Upper and Lower Lough Macnean and Lough Melvin, were surveyed in 1989-91, they had chlorophyll *a* and phosphorus concentrations typical of mesotrophic conditions. Recent monitoring of Lough Melvin in support of its consideration as a Special Area of Conservation has revealed a decline in water quality throughout the catchment since 1990. Based on a six month sampling programme from July 2001, mean concentrations of total phosphorus (36 µg P / L) and chlorophyll *a* (10 µg / L) now indicate a eutrophic status may be appropriate.

3.3.7 Small lakes

Knowledge about the status of small lakes in Northern Ireland is based on the results of a survey of all lakes in Northern Ireland that are between 1 and 100 hectares in area. This was conducted in the summers of 1988 to 1990 and showed that enrichment with phosphorus was widespread (Gibson *et al*., 1995). For the 495 lowland lakes, classifying the data according to the OECD trophic categories gave a breakdown of trophic categories where 69.9% of lakes were either eutrophic or hypertrophic (Table 3.4). Few of these received urban drainage from towns or villages. A synoptic survey carried out in

March 2002 sampled over 100 lakes selected for conservation and other interests and confirmed the widespread occurrence of eutrophic lakes throughout Northern Ireland.

Table 3.4 Distribution of total phosphorus in 495 lowland lakes in Northern Ireland

Category	TP Concentration	Number of lakes	%
Oligotrophic	0-10 μg P/ L	3	0.6
Mesotrophic	11-35 μg P/ L	146	29.5
Eutrophic	36-100 μg P/ L	192	38.8
Hypertrophic	>100 μg P/ L	154	31.1

Conclusion 3: Trophic Status of Lakes Lough Neagh and Lough Erne are hypertrophic and eutrophic respectively. Lough Melvin and a large number of small lakes throughout Northern Ireland are also showing evidence of eutrophication or deteriorating eutrophic status. The role of nitrate in supporting eutrophication of these lakes cannot be ruled out. However, phosphorus is generally the nutrient limiting maximum algal production in these lake systems, and effective measures taken to control eutrophication must lower phosphorus inputs.

3.4 Trophic conditions in Northern Ireland - Rivers

3.4.1 Indicators of eutrophication in rivers

Chemical

Chemical indicators for trophic status of rivers are less developed than those for lakes. In the guidance produced for implementation of the UWWT Directive (DoE (NI), 1999), the UK authorities suggested that an annual average phosphate concentration over 0.1 mg SRP / L would indicate possible or future eutrophic problems in running waters. This limit does not take account of the current condition of the river compared to a reference condition for that type of river and is most likely applicable to large lowland rivers.

In contrast research in the Republic of Ireland (RoI) has shown that the phosphate concentrations of rivers of differing biological water quality status follows concentration ranges broadly similar to those developed for the trophic status of lakes by the OECD (McGarrigle, 1998). Based on this the authorities in RoI have set statutory phosphate standards for rivers that require "unpolluted" rivers to have a maximum annual median of 0.03 mg MRP / L. This classification uses the phosphate fraction MRP, which is molybdate reactive phosphorus and is measured on unfiltered water samples. In most instances in Northern Ireland, concentrations of this fraction are only slightly higher than those of soluble reactive phosphorus, which is MRP measured on a filtered sample. It is apparent therefore that the standard for the RoI is more stringent than the standard currently suggested by the UK authorities.

Biological

The standardised monitoring of macrophytes growing in UK rivers for the purpose of determining trophic status assessment has been based on the methodology developed by Holmes (1995) and Holmes *et al.* (1999). This methodology, widely used by the UK regulatory agencies, produces information on the composition and abundance of the aquatic macrophyte flora. Stretches of river are surveyed to determine their species composition, and an estimate of their individual abundance is recorded. This can then be collated into a Mean Trophic Rank (MTR) score from which subsequent classifications can be derived as described in Table 3.5.

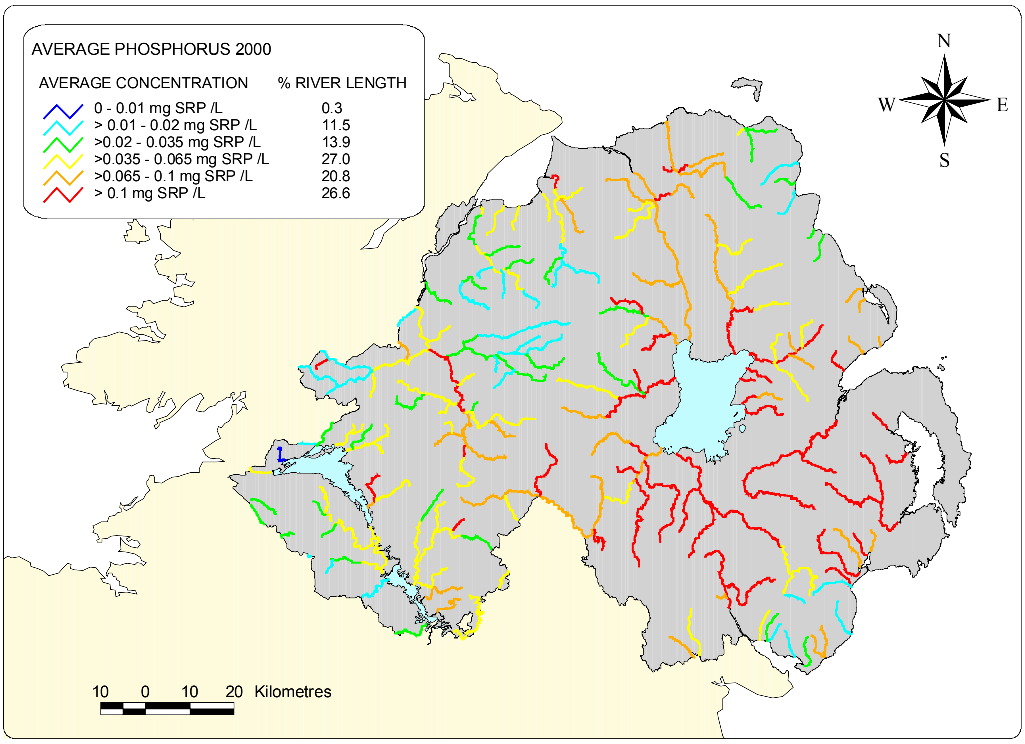
Table 3.5 Macrophyte classifications based on Mean Trophic Rank

Class	Class Descriptor	Trophic Ranking Score Values
1	Waters that are unlikely to be enriched	>65
2	Waters that are enriched or are showing the potential to become enriched	25 – 65
3	Waters already enriched with a degraded macrophyte flora	<25

3.4.2 Trophic status of rivers

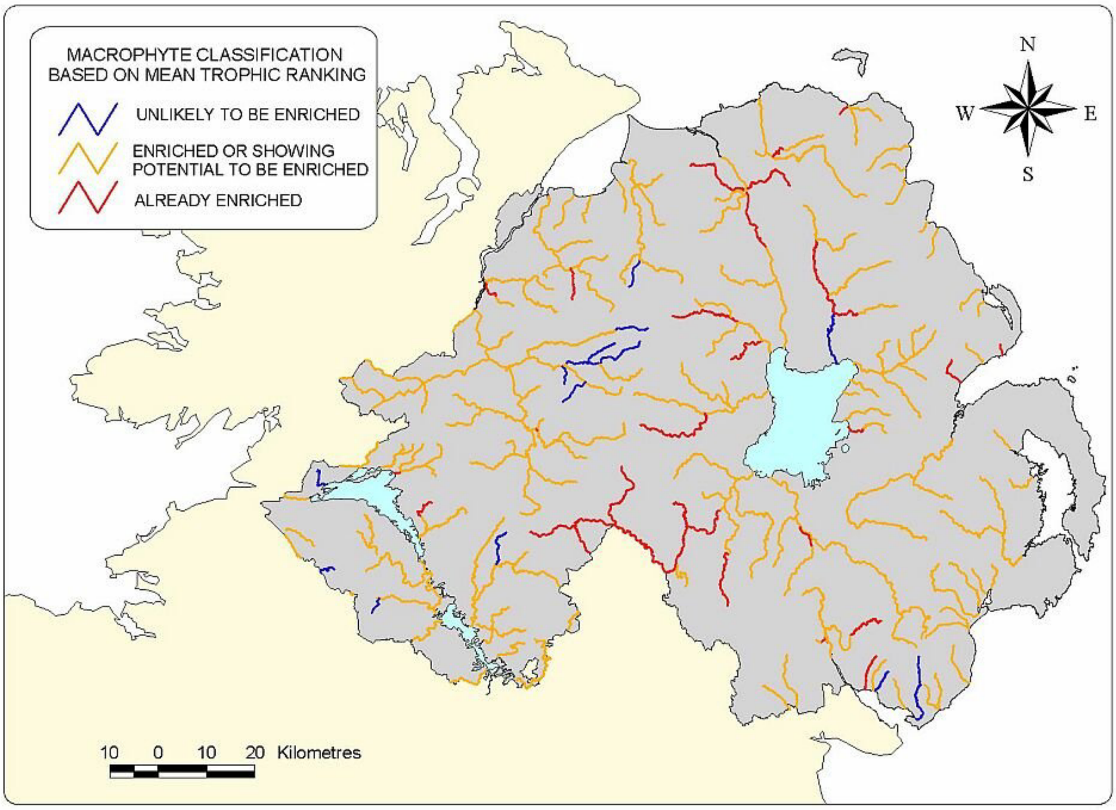
Figure 3.2 shows that 27% of river length monitored in 2000 exceeded the proposed UWWT Directive guidance level of 0.1 mg SRP / L level and a further 21% of river length monitored approached this level (i.e. 0.065-0.10 mg P / L). If a more stringent standard of 0.035 mg P/L is taken, which would be consistent with the relationship between water quality and phosphorus found in rivers of the Republic of Ireland, then 74% of river length can be defined as enriched.

Figure 3.2 Mean concentrations of soluble reactive phosphorus in rivers of Northern Ireland in 2000.



With respect to aquatic macrophytes, the most recent survey was in the summer of 1998 (Fig 3.3). It was based on 293 established monitoring sites across Northern Ireland (IRTU, 1999).

Figure 3.3 Trophic status of rivers in Northern Ireland in 1998 based on the mean trophic ranking macrophyte classification.



The key findings were that:

1. the few rivers that were found to be "unlikely to be enriched" occurred only in remote regions where man-made pressures were low;
2. the majority of river reaches were "already enriched", or "enriched or showing the potential to become enriched"; and
3. significant lengths of the rivers shown to be "already enriched", or "enriched or showing the potential to become enriched" occurred where land use is intensive and/or downstream of point discharges.

Further studies will be required to gather additional data to update the findings of the 1998 survey.

Conclusion 4: Trophic Status of Rivers. Macrophyte classifications suggest that the plant communities in the majority of rivers in Northern Ireland are representative of trophic status typical of "already enriched", or "likely to become enriched" waters. Concentrations of phosphate measured in the rivers are consistent with this assessment.

3.5 Trophic conditions in Northern Ireland - Marine waters

3.5.1 Indicators of eutrophication in the marine environment

The OSPAR Convention is an international agreement for the protection of the marine environment of the North-East Atlantic. OSPAR has developed a Strategy to Combat Eutrophication, including a Common Procedure, which sets out the criteria to identify eutrophic problem areas, potential problem areas and non-problem areas. Common assessment criteria have been developed and were agreed by the OSPAR Commission in June 2002.

The key criteria used in 2001 to assess the trophic status of estuarine and coastal waters in Northern Ireland were based on the guidance produced for implementation of the UWWT Directive (DOE (NI), 1999). These criteria can be broken down into chemical and biological factors as follows (EHS, 2001):

Chemical criteria

- Enrichment is considered to exist in coastal waters when winter nutrient concentrations significantly exceed 0.74 mg NO_3 / L in the presence of at least 6.2 μg / L of available phosphorus;
- Chlorophyll levels in excess of 10 μg / L (MPMMG, 1997); and
- High oxygen concentrations in excess of 120% saturation are considered to be supersaturated and may indicate high rates of photosynthesis by algae or seaweed.

Biological criteria

- algal biomass;
- algal species composition;
- presence/absence of potentially toxic or nuisance algae; and
- the frequency of the closure of shell fisheries.

3.5.2 Trophic status of sea loughs

On behalf of EHS, DARD has carried out surveys of trophic status of the five major sea loughs of Northern Ireland (Foyle, Larne, Belfast, Carlingford and Strangford) and of the Quoile Pondage (Service *et al*., 1996; Service, 2000: Taylor *et al*., 2001, Charlesworth, *et al* 2001). Inner Belfast Lough, the tidal Lagan and the Quoile Pondage are eutrophic. Inner Belfast Lough receives the majority of its total nitrogen loading from an industrial point source and direct discharging WWTWs. It has high nutrient levels and sporadic algal blooms, including toxic species of algae. The tidal reaches of the River Lagan are also impacted significantly by the nutrient inputs to inner Belfast Lough. It can be seen however from Figures 3.2 and 3.3 that the freshwater reaches of the River Lagan are also showing signs of nutrient enrichment, and, therefore, a nutrient budget for this entire catchment is required.

The tidal reaches and the lower reaches of the Quoile estuary have high nutrient concentrations that result in algal blooms with evidence of nitrogen limitation. It can be seen from Figures 3.2 and 3.3 that the Quoile River is also showing signs of nutrient enrichment. Further work is currently ongoing to complete a nitrogen budget of inputs to the Quoile River to determine the need to designate this catchment as an NVZ.

Studies are ongoing in Lough Foyle, the Newry River estuary and the northern end of Strangford Lough to examine the trophic status of these areas. To date, the estuarine section of the Lower Bann has not been included in studies on the trophic status of sea loughs. Given the enriched nature of the outflow water from Lough Neagh and the potential influence of the Lower Bann catchment, the Bann estuary may be enriched. Further work is needed to assess the trophic status and nitrate sources of these estuarine waters.

3.5.3 Trophic status of coastal waters

Mean concentrations of nitrate have been measured routinely by DARD scientists at coastal stations along the County Down coastline in late winter when nitrate concentrations are at their maximum. None of these coastal stations is enriched with nitrate under the proposed definition in Section 3.5.1, which is to be expected since there are no large sources of nitrate along this part of the County Down coast that might be responsible for any enrichment in this area.

3.5.4 Trophic status of the Eastern Irish Sea

The European Commission has argued that the Eastern Irish Sea, which receives the discharge from English rivers such as the Mersey, merits a eutrophic classification. There is evidence, supported by a clear relationship between nutrient concentrations and salinity in Liverpool Bay, of nutrient enrichment in the plume of lower salinity water emerging from the Mersey into Liverpool Bay. However the effect of this enrichment on coastal waters around Northern Ireland appears to be slight as there is a generally northward passage of water through the Eastern Irish Sea that carries water east rather than west of the Isle of Man. This water exits through the North Channel along the Scottish coast. DARD observations confirm the conclusions of numerical modelling of water movement in the Irish Sea that there is little or no westward mixing of English coastal waters south of the Isle of Man. Hence the discharge of nutrients from the Eastern coastal region has little significance for Northern Ireland waters.

Conclusion 5: Trophic Status of Marine Waters. The open coastal waters around Northern Ireland are not considered to have a eutrophication problem, but eutrophic conditions have been found in Inner Belfast Lough, the tidal Lagan and the Quoile Pondage. The major sources of nitrogen to Inner Belfast Lough and the tidal Lagan are from industry and waste water treatment works. Therefore these areas have been designated under the Urban Waste Water Treatment Directive. However it may be that the whole Lagan catchment will merit designation as a NVZ if agriculture is found to be a significant (>20%) source of nitrate. At present the sources of nitrate to the Quoile Pondage are being evaluated and, if the agricultural component is found to be significant, the Quoile catchment will also merit a NVZ designation to protect water quality. Further investigations of trophic status and nitrate sources are also required for a number of other areas: Lough Foyle, Strangford Lough and the estuaries of the Newry River and Lower Bann.

3.6 Summary of trophic conditions of surface waters in Northern Ireland

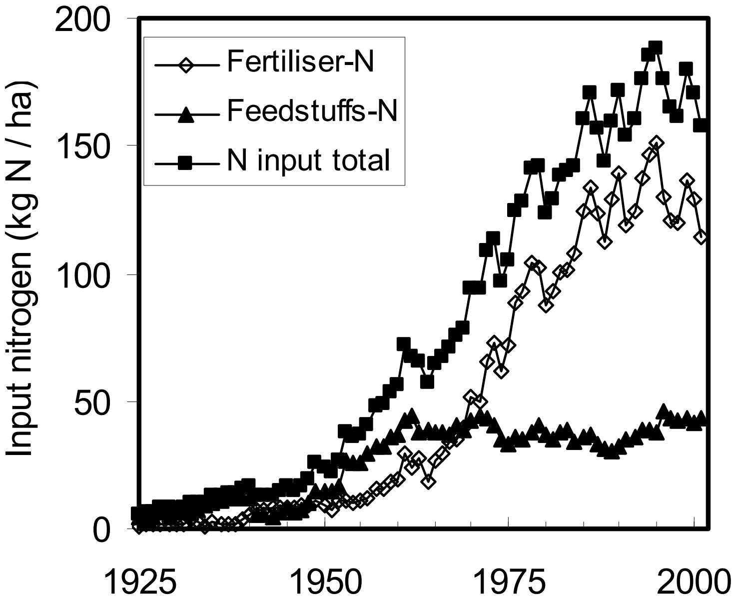
It is evident that eutrophic conditions are widespread throughout Northern Ireland and indeed eutrophication is regarded as the most serious water quality issue facing Northern Ireland (EHS, 1999). Lough Neagh and Lough Erne are both eutrophic and together their catchments drain approximately 44% of the land area of Northern Ireland. Outside these catchments widespread eutrophic conditions have been found in both rivers and small lakes. Inner Belfast Lough, the tidal River Lagan and the Quoile Pondage are recognised as being eutrophic, and therefore the catchments of the River Lagan and River Quoile also drain into eutrophic waters. In addition, there are other areas within the sea loughs that require further investigation. Open coastal waters around Northern Ireland are not considered to have a eutrophication problem.

4 AGRICULTURAL NITROGEN AND NITRATE LOSSES

4.1 Use of nitrogen by agriculture in Northern Ireland

Managed nitrogen inputs to agriculture in Northern Ireland consist of fertilisers and nitrogen in animal feeds. Prior to 1969 inputs in feedstuffs exceeded inputs in fertiliser but since then fertilisers have been the dominant source (Fig 4.1). However, animal feedstuffs continue to represent a significant source of nitrogen, accounting for 26% of the total inputs from 1996 to 2001. Over the period of monitoring the rivers flowing into Lough Neagh from 1970, nitrogen inputs to agriculture have increased by approximately 80% but most of this increase occurred before 1985 (Fig 4.1).

Figure 4.1 Nitrogen inputs from fertilisers and imported animal foodstuffs to agriculture in Northern Ireland. Inputs expressed per area of crops and grass in Northern Ireland.



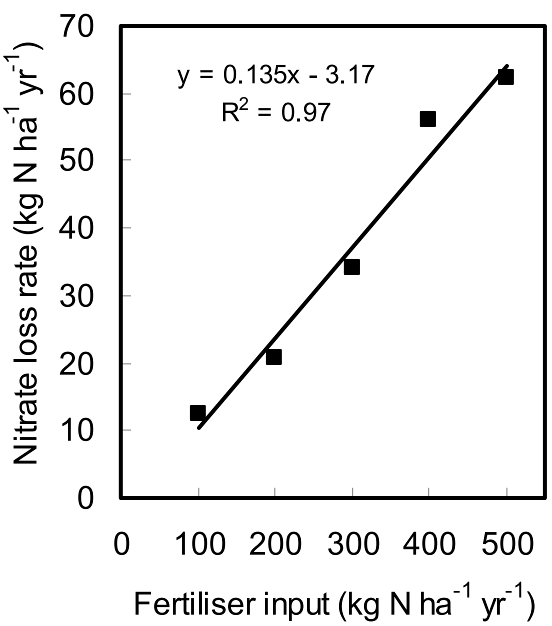
4.2 Fate of nitrogen in agriculture

The nitrogen cycle in soils is an open one as significant exchanges with the atmosphere occur. Precipitation inputs are significant in some European countries and in parts of England due to atmospheric pollution, but in Northern Ireland they are low at 11 kg N / ha / year due to the strong oceanic influence on climate (Jordan, 1997). Nitrogen fixation by plants also adds nitrogen to the soil from the atmosphere. While historically this must have been the major source of nitrogen to agriculture in Northern Ireland, nitrogen fixation has been suppressed by the use of nitrogen fertilisers and the decline of clover in grass swards.

A major study by DARD scientists was recently completed on the nitrogen cycle in grassland using grazed grass plots at the Agricultural Research Institute of Northern Ireland (ARINI) at Hillsborough (Watson *et al.*, 2000a&b). The study investigated the impact of varying inputs of nitrogen fertilisers on losses of nitrate and other nitrogen compounds to drainage, which was monitored throughout the year. Amounts of nitrogen retained by the grazing animal and losses of nitrogen to the atmosphere were also established. This study lasted over nine years, encompassing both wet and dry years and provides a strong scientific basis for assessing the impact of agriculture on the concentrations of nitrate observed in the rivers of Northern Ireland.

Each year there was a strong correlation between nitrogen fertiliser and the nitrate in drainage water. Losses of nitrate took place primarily during the winter, but the amounts varied from year to year, being highest in the winter following the dry summer of 1995. The average loss of nitrate showed a near linear relationship with nitrogen fertiliser inputs (Fig 4.2). The slope of 0.135 indicates that nitrate losses were 13.5% of nitrogen inputs. This relationship has been used to assess the contribution of agriculture to nitrate in Northern Ireland rivers.

Figure 4.2 Nitrate loss rates vs nitrogen fertiliser application rates. Experimental data based on period 1989-1997 (Watson *et al.*, 2000a)



Losses of nitrogen occur to both the atmosphere and to water and it is apparent that nitrate losses to drainage are a comparatively small proportion of nitrogen inputs. Studies by DARD scientists on nitrate leaching suggest that lower concentrations and loss rates of nitrate are observed in drainage waters from grassland in Northern Ireland compared with those observed in other parts of the UK, even though fertiliser usage is similar (Smith and Stewart, 1989). Additional losses of organic nitrogen and ammonium to drainage are likely to account for a further 1% of the current nitrogen inputs giving 14% of nitrogen inputs lost via drainage (Watson, *et al*., 2000b). At present (1996-2001 average) the nitrogen input from fertiliser and animal foodstuffs to the area of crops and grass in Northern Ireland is 168 kg N / ha / yr. Only 19% of this input is retained as agricultural product so that, in total, only 33% of nitrogen inputs can easily be accounted for. The remaining 67% is either lost to the atmosphere or accumulates as organic nitrogen in the soil. Atmospheric losses are the more important and the relevance of these to the Nitrates Directive will be considered in Section 7.

5 NITRATE SOURCES IN NORTHERN IRELAND

5.1 Background

Once a problem with nitrate pollution is identified, either as nitrate concentrations exceeding or increasing towards the mandatory standard or as eutrophication of a surface water, the next step must be to identify the source of the inputs of nitrogen to the water body. As previously discussed, it has been suggested by the European Commission that catchments of such impacted waters, where agriculture is a significant (more than 20%) source of nitrate, must be designated as NVZs.

5.2 Nitrate sources in the Lough Neagh catchment

5.2.1 Methodology

The weekly DARD sampling programme of the six major rivers flowing into Lough Neagh enables an accurate estimation of nitrate losses from each catchment. Loadings represent the product of river flow times nitrate concentration and so are influenced by runoff volumes as well as concentration. Inputs of nitrate to the rivers from towns within the catchments were calculated using monitoring data, provided by EHS, of effluents from waste water treatment works. The importance of the following sources of nitrate was also determined:

- losses from agricultural land, excluding rough grazing, calculated using the 13% loss coefficient;
- losses from rough grazing and upland forestry, which were based on AESD monitoring results from upland catchments; and
- nitrification determined as an estimate of the generation of nitrate within the river through the oxidation of ammonium. This was based on a consideration of the ammonium budgets of each river (Foy, 2002a).

5.2.2 Loading Trends

Nitrate loadings from the catchment of Lough Neagh show an underlying increase with time (Fig 5.1). The rate of increase was 0.27 kg N / ha / yr with 95% confidence limits of ± 0.15 kg N / ha / yr. This trend accounts for some 33% of the observed variation as there is considerable variation around the trend line with evidence of the peaks in loss rate occurring every six years that were observed for nitrate concentrations (see also Fig 2.5). To allow for this variation, recent loss rates have been averaged over a six-year period, 1994-1999, when the average loss rate was 18 kg N / ha / yr. Over this period loss rates varied between 23 kg N / ha /yr in 1996 and 14 kg N / ha / yr in 1994. For individual rivers in the Neagh catchment, the highest loss rate of 25 kg N / ha / yr was from the Ballinderry River and the lowest, 13 kg N / ha / yr, from the River Blackwater (Fig 5.2). Although the Upper Bann had the highest nitrate concentrations, the amount of nitrate lost per unit area of 17 kg N / ha / yr ranked second lowest out of the six rivers. This is because the Upper Bann produces the least runoff per unit area of the six rivers flowing into Lough Neagh so that the high nitrate concentrations of the Upper Bann were counterbalanced by low flows. Therefore a river with the highest nitrate concentrations was a below average contributor to nitrate in Lough Neagh (Fig 5.2).

Figure 5.1 Nitrate export rates from the rivers flowing into Lough Neagh, 1971-1999. Export rates normalised to catchment area of 4450 km^2.

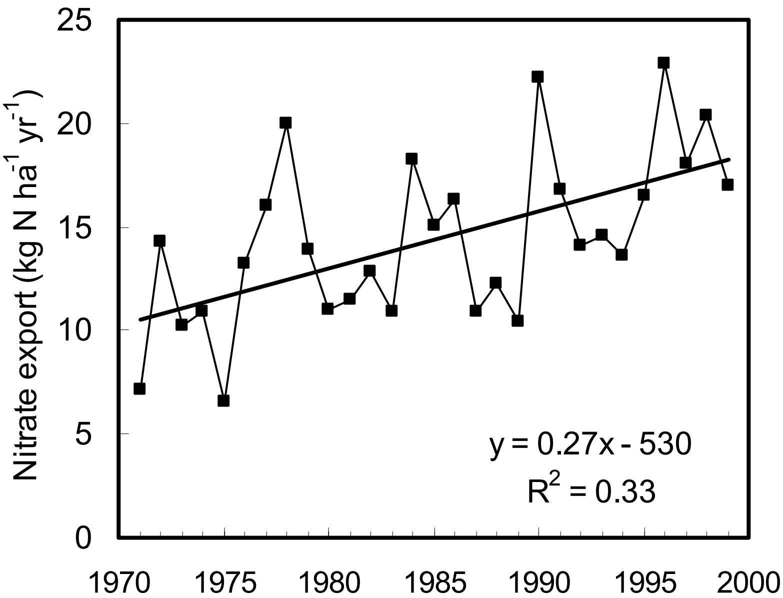
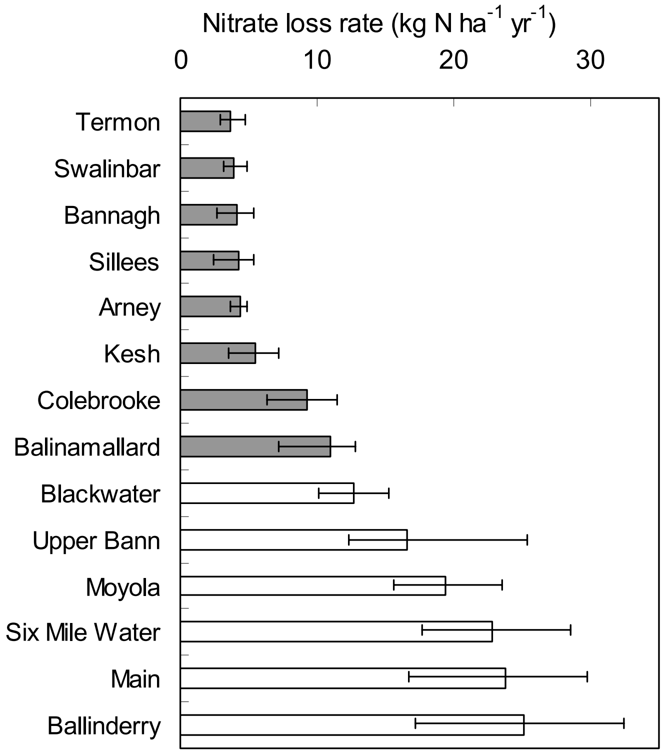


Figure 5.2 Nitrate export rates from the Lough Erne (shaded) and Lough Neagh catchments, 1994-99. Bars denote range of annual values from 1994 to 1999.



<u>5.2.3 Nitrate sources 1994-1999</u>

Nitrate losses from crops and grass accounted for 75% of the total nitrate load to the rivers flowing into Lough Neagh (Table 5.1). This loading was based on the assumption that the rates of nitrogen use in the Neagh catchment were similar to those of Northern Ireland. No other component of the budget accounted for more than 8% of the annual inputs. The final category in the budget breakdown, designated ‘other’, was calculated as the difference between the river nitrate export and the sum of the other components and accounted for 8% of the nitrate load. Forestry and rough grazing made the smallest contribution (2%) to the loading reflecting the small area devoted to these land uses which together represented 15.4% of the total area. In addition, very low concentrations of nitrate are measured in streams from uplands and forests, which were less than 10% of concentrations observed in rivers where they entered Lough Neagh, indicating upland loss rates of only 2 kg N / ha / yr.

As the contribution from towns is based on direct measurement, it may be concluded that WWTWs cannot be a major source of nitrate to Lough Neagh. Septic tanks discharge nitrogen as ammonium rather than nitrate and their contribution is included in the nitrification contribution. They are not a significant source. In contrast the large amounts of nitrate that cannot be accounted for by towns, rough grazing and nitrification are consistent with the predicted amounts of nitrate leaving agricultural land.

Table 5.1 Sources of nitrate exported to Lough Neagh 1994-1999. Includes towns that discharge directly to the Lough.

Source	Nitrate loading	
	Tonnes N / yr	%
Towns	644	8
Nitrification	551	7
Agricultural land	6269	75
Rough grazing & forestry	137	2
Other land	624	8
Total	8225	100

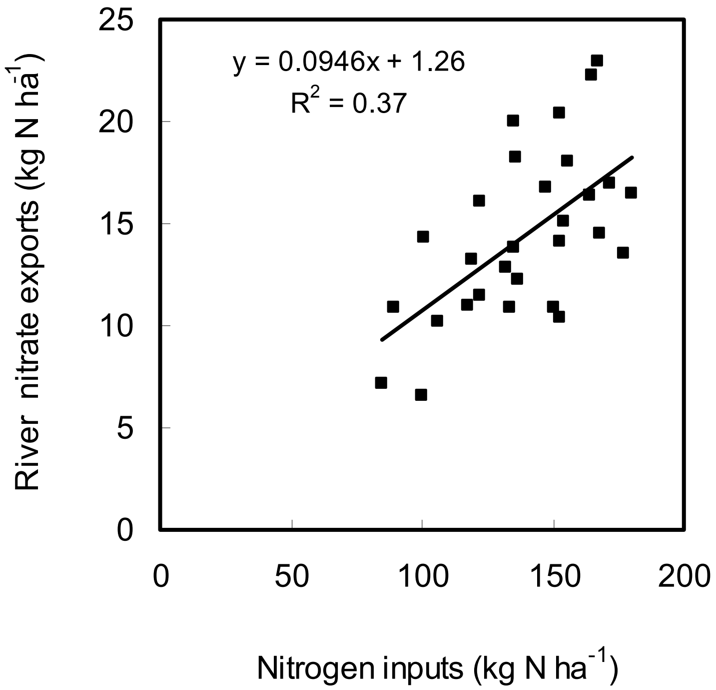
5.2.4 Nitrate sources 1971-1976

The nitrate budget for the Lough Neagh rivers was repeated for the period 1971-76 and is compared with the rivers' budget for 1994-99 (Table 5.2). The output from towns has been adjusted for the lower urban population in 1971-76. The export from agricultural land is predicted from the use of nitrogen by agriculture at this period of 100 kg N / ha / yr and predicts a nitrate load in the Lough Neagh rivers from lowland agriculture of 2835 tonnes N / yr. The measured river loading from 1971 to 1976 was 4044 tonnes N / yr or 42% lower than in the period 1994 to 1999. The increase in river nitrate loading of 2983 tonnes N / yr can almost entirely be attributed to the increased inputs of nitrogen by agriculture, which is estimated to have increased nitrate loads by 2780 tonnes N/ yr. By comparison the increase in nitrate from WWTWs, is calculated to have been only 26 tonnes N / yr.

Table 5.2. Sources of nitrate exported from Lough Neagh rivers 1971-1976 in comparison to 1994-1999.

Nitrate Source	Tonnes N / yr. 1971-1976	1994-1999	Change
Towns	362	388	26
Nitrification	482	482	0
Agricultural land	2938	5615	2677
Rough grazing & forestry	128	128	0
Other land	134	414	280
Total (measured)	4044	7027	2983

Figure 5.3 Annual nitrate exports from Lough Neagh rivers vs annual inputs of nitrogen to agriculture in Northern Ireland from 1971 to 1999. Note: Nitrogen inputs are expressed per unit area of crops and grass. River exports are expressed relative to river catchment area.



5.2.5 Nitrate loads vs use of nitrogen by agriculture

The plot of river nitrate export vs nitrogen inputs shows a considerable scatter and the correlation between the two accounts for 37% of the variation (Fig 5.3). The slope of the regression indicates that, for every increase of 10 kg N / ha used by agriculture in the catchment, nitrate export rate increased by 0.94 kg N / ha. However the two sets of data in Figure 5.3 are normalised to different areas: the agricultural nitrogen input refers to the area of crops and grass, while the nitrate export is normalised to the river catchment area, of which only 74% was utilised for crops and grass. When this difference is allowed for, then the proportion of the additional nitrogen used by agriculture that is lost as nitrate in the Neagh catchment is 0.126 which concurs with the experimentally derived value of 0.135 found for nitrate losses from grazed grassland (Figs 4.2 & 5.3).

5.2.6 Lough Neagh nitrate loadings summary

Nitrate losses from the Lough Neagh rivers, both in terms of magnitude and trends with time, have behaved in a manner similar to nitrate exports predicted from experimentally derived relationships between fertiliser nitrogen inputs and nitrate losses. Lowland agriculture, the sum of the areas devoted to crops and grass, is by far the largest contributor to the nitrate losses to Lough Neagh. The contribution of 76% for the period 1994-99 may be a conservative estimate, as it is derived from an average rate of use of nitrogen by agriculture in Northern Ireland. In contrast, the Lough Neagh catchment contains proportionately more pigs and poultry and hence is likely to have higher nitrogen inputs than in the remainder of Northern Ireland. The 71% increase in nitrate loadings since 1971-76 can be ascribed to increased nitrate exports from agricultural land and the greater use of nitrogen by agriculture. The scope for urban inputs to significantly contribute to nitrate loading is extremely limited. The average nitrate loss from all sectors to the Lough Neagh rivers of 7027 tonne N / yr between 1994 and 1999, compares with the loading to rivers of nitrate and ammonium of 677 tonnes N / yr from waste water treatment works over the same period (Foy, 2002a).

5.3 Nitrate sources in the Lough Erne catchment

5.3.1 Methodology

Prior to 1989, the sampling record for the eight rivers that drain the Northern Ireland portion of the Erne catchment is less comprehensive than for the Lough Neagh catchment, but there is good coverage for the 1990s from which nitrate loads and sources can be assessed.

5.3.2 Nitrate loss rates 1994-1999.

Loss rates from individual rivers in the Lough Erne catchment were lower than from any of the Lough Neagh rivers with an average loss rate of 6.2 kg N / ha / yr compared to an average of 18.1 kg N / ha / yr for the Lough Neagh catchment (Fig 5.3). Nitrate losses from the eight rivers were 810 tonnes N / yr but towns and villages contributed only 1% of this nitrate load, while drainage from forest and rough grazing contributed 6% (Table 5.3). The extremely low urban contribution reflects: a) the low urban population in all the Erne river catchments and b) ammonium rather than nitrate was the principal nitrogen fraction in most effluents from WWTWs in the catchments. The breakdown excludes inputs from Enniskillen, the only large town, as Silverhill WWTW, which serves the town, discharges directly into Lough Erne and is not part of the river-monitoring network. However, this omission makes little difference to the conclusion that towns are a trivial nitrate source as the discharges of ammonium of 40.5 tonnes N / yr and nitrate of 2.1 tonnes N / yr from Silverhill are small in comparison with the river nitrate loading of 810 tonnes N / yr. The value for nitrification, based on a consideration of ammonium sources and exports from the rivers, was also low. Thus agriculture, estimated by difference, was estimated to contribute 92% of the annual loadings.

Table 5.3 Sources of nitrate exported from eight Lough Erne rivers 1994-1999.

Source	River nitrate inputs	
	Tonnes N / yr	%
Towns	7.5	0.9
Nitrification	6.6	0.6
Agricultural land	747.6	92.2
Rough grazing & forestry	50.3	6.2
Total (measured)	810.5	100.0

5.3.3. Agricultural nitrate loss rates

The intensity of agriculture in the Erne catchment is often low, especially for the rivers in West Fermanagh such as the Arney and Sillees. Inputs of agricultural nitrogen are estimated to average 117 kg N / ha compared to an average for Northern Ireland of 174 kg N / ha. After allowing for this lower use of nitrogen, predicted nitrate loss rates calculated as 13.5% of nitrogen inputs, were still greater than the observed nitrate exports from seven of the eight rivers. The sole exception was the Ballinamallard River where there was good agreement (Foy, 2002b). This in turn was the catchment with the highest level of agricultural intensity.

5.3.4. Trends in nitrate loss rates

In six of the eight rivers the nitrate loss rates show statistically significant increases with time (Foy, 2002b). In each instance the confidence limits for the rates of increase in the Erne rivers were wide. The correlations with time were low and rates of increase were lower than measured for the Lough Neagh river catchments.

Conclusion 6: **Nitrate Sources** Agriculture is the most significant source of nitrate in both Lough Neagh and Lough Erne contributing 75% and 92% of the total nitrate loading respectively. While the Nitrates Directive would mandate the control of nitrogen in manure applications in these catchments, there is likely to be little improvement in the eutrophic status of these waters unless phosphorus losses to water are controlled simultaneously.

6 IMPLICATIONS OF OPTIONS FOR POSSIBLE NVZ DESIGNATIONS IN NORTHERN IRELAND

6.1 Land areas within possible NVZs

Approximately 0.1% of the land area of land in Northern Ireland is covered by the three current NVZs. The addition of up to five further NVZs that are based on groundwater exceedences would be unlikely to increase the total land area covered to 0.2%. This Report has highlighted a number of catchments where eutrophication occurs or may occur. These areas may therefore merit designation as additional NVZs in Northern Ireland. Their respective catchment areas are summarised in Table 6.1. These areas are listed without prejudice to the outcome of the decision-making processes required for designation.

Table 6.1 Existing NVZ land areas within Northern Ireland and areas of catchments draining into eutrophic surface waters.

Catchments	Environmental issue	Land area* (km^2)	Land area as % of Northern Ireland	Cumulative area as % of Northern Ireland
1 Current NVZs Comber & Clogh Mills	Groundwater >50 mg NO_3 / L	16	0.1	0.1
2 Lough Neagh (less Lower Bann)	Freshwater eutrophication	4086	30.0	30.1
3 Lough Erne (Upper and Lower)	Freshwater eutrophication	1829	13.4	43.6
4 Quoile	Marine and freshwater eutrophication	267	2.0	45.6
5 Strangford Lough (less Quoile)	Marine and freshwater eutrophication	505	3.7	49.3
6 Lower Bann	Marine and freshwater eutrophication	922	6.8	56.0
7 Newry River	Marine and freshwater eutrophication	275	2.0	58.1
8 River Lagan	Marine and freshwater eutrophication	592	4.4	62.4
9 Foyle	Marine and freshwater eutrophication	2000	14.7	77.1

Catchment areas should be considered as approximate and to be confirmed by additional catchment delineation.

The first grouping shows the area of land within existing NVZs. Nutrient budgets are complete for catchments 2 and 3 and are in progress for catchment 4. Further studies are required for the remaining catchments. This selection does not include the catchments of many of the small lakes known to be eutrophic. Similarly it does not specifically consider the drainage basins of the rivers that have been highlighted in the report as showing signs of enrichment (Sections 3.3.6, 3.3.7 and 3.4.2).

6.2 Cross-border implications

Article 3(3) of the Nitrates Directive 91/676 provides that, where waters identified under the Directive "are affected by pollution from waters from another Member State draining directly or indirectly into them, the Member State whose waters are affected may notify the other Member State and the Commission of the relevant facts". Article 3(3) places Member States under an obligation "to organise, where appropriate with the Commission, the concertation necessary to identify the sources in question and the measures to be taken to protect the waters that are affected in order to ensure conformity with the Directive". In addition, Article 3(3) of the Water Framework Directive (2000/60/EEC) requires Member States to "ensure that river basins covering the territory of more than one Member State are assigned to an 'International River Basin District'". Article 3(4) of the Water Framework Directive further provides that the Member States concerned are required to work together to ensure the co-ordination necessary to achieve the obligations laid down in the Water Framework Directive.

As Northern Ireland shares a land border with another Member State, the Republic of Ireland (RoI), it is required by the Nitrates Directive and Water Framework Directive to co-ordinate its approach to the management of shared waters with the RoI. It is therefore essential to address the inputs of nutrients to shared waters.

The publicly stated preferred approach to implementation of the Nitrates Directive in the RoI is the "whole territory" approach under Article 3(5) (DoELG, 2002). Northern Ireland has adopted a "discrete zoning" approach under Article 3(2). It will be essential that any differences in the implementation approaches to the Nitrates Directive in Northern Ireland and the RoI nevertheless allow the objectives of the Water Framework Directive to be fully met within the International River Basin Districts.

6.3 Implications for achievement of "Good Status" under the EC Water Framework Directive

Under the Water Framework Directive, all water bodies must achieve "Good Status" by 2015. In addition, nutrient sensitive areas, such as NVZs, must be included on a Register of Protected Areas by Member States by 2004. These Protected Areas must also achieve the specific requirements of their designations by 2015. The current widespread eutrophic conditions of surface waters in Northern Ireland are the product of decades of high nutrient loadings. It will therefore require immediate and effective action to reduce the inputs of both nitrogen and phosphorus to these waters in order to meet the obligations of the Water Framework Directive.

7 DENITRIFICATION.

7.1 Background

The Nitrates Directive in Annex III, Section 2(b) states that Member States may use a number of criteria as justification for permitting higher manure N application rates than the specified amount of 170 kg N / ha / yr. One of these criteria is the presence of soils with an 'exceptionally high denitrification potential'. Microbial reduction of nitrogenous oxides, nitrate and nitrite, is known as biological denitrification. The principal products are di-nitrogen (N_2) and nitrous oxide (N_2O), though nitric oxide (NO) has occasionally been detected. These gases are lost to the atmosphere where nitrous oxide may be contributing to global warming as it is a greenhouse gas. Denitrification will lower soil nitrate concentrations and, thus, the amount of nitrate lost to watercourses.

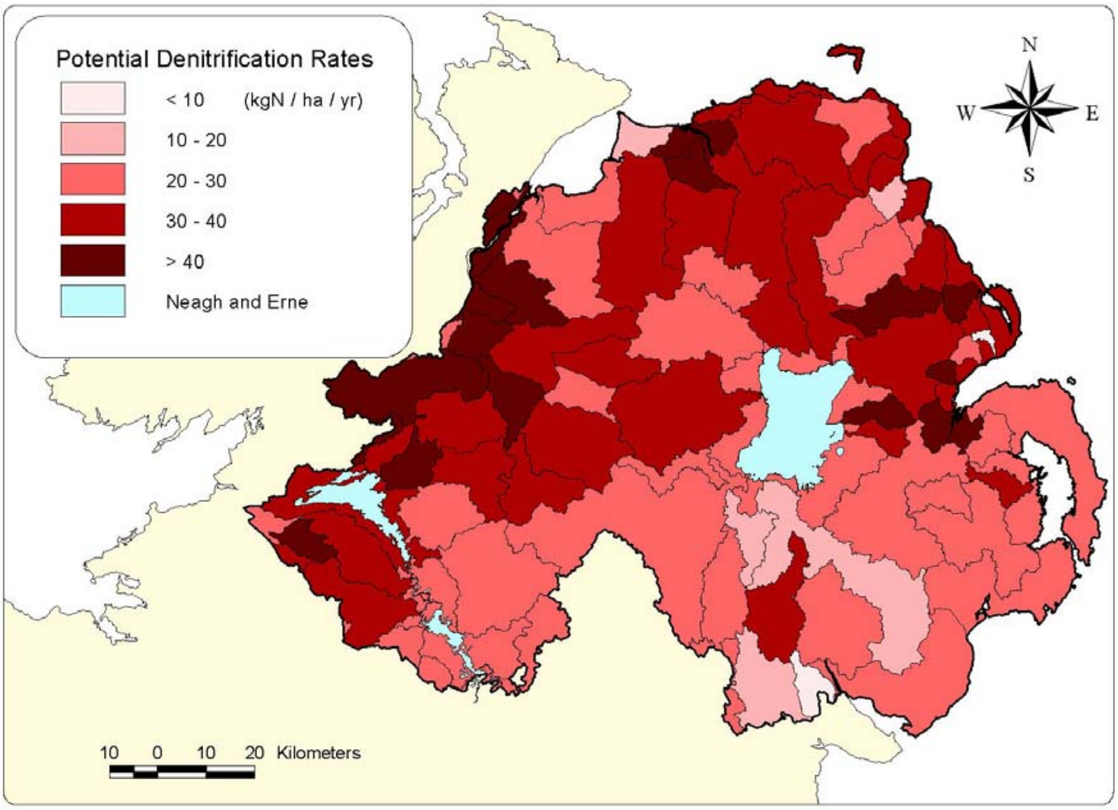
7.2 Denitrification rates

Denitrification is considered to be an important pathway and indeed the major pathway for nitrogen loss in the soils of Northern Ireland. Emissions of nitrous oxide arising from denitrification processes operating within agricultural soils have been modelled for the UK by Brown *et al*. (2002). Using census and other data for 1990, they estimated that emissions of nitrous oxide are highest in the SW of England and in Northern Ireland. For Northern Ireland, the mean nitrous oxide loss rate is 5 kg N / ha / yr. Research indicates that the nitrous oxide loss accounts for approximately a quarter of the total nitrogen losses resulting from denitrification. Thus, the combined di-nitrogen and nitrous oxide loss for Northern Ireland as a result of denitrification was estimated to be of the order of 20 kg N / ha / yr.

7.3 Catchment denitrification rates

AESD has recently modelled denitrification losses on a river catchment basis. Total denitrification losses across Northern Ireland were modelled using soil HOST (Hydrology Of Soil Type) class data (in the form of standard percentage runoff values), annual runoff (1961-90) and N-fertiliser rates (derived from Farm Census data) and mapped relative to ARINI, Hillsborough. Actual total denitrification rates at ARINI were known (24.7 kg N / ha / yr) based on work by Jordan, 1989. The modelled rates were validated against the Brown *et al*., 2002 model and then used to calculate the mean denitrification loss rates for each major river catchment (Fig 7.1). Losses from denitrification were high throughout Northern Ireland compared with those in GB. River catchments in the west had the highest denitrification losses within Northern Ireland, despite the fact that fertiliser inputs are lower than average. This analysis provides the most probable explanation for the lower than expected nitrate losses in the Erne catchment where the higher frequency of soils with impeded drainage promoted higher losses through denitrification. In this respect it may be noted that the river in the Erne catchment with the best drained soils, the Ballinamallard, was the only catchment to give good agreement between predicted and measure nitrate loss rates.

Figure 7.1 Modelled annual losses of nitrogen from the denitrification of nitrate within river catchments.



At present, concentrations of nitrate in rivers in Northern Ireland are broadly as expected from experimental work on the relationships between nitrogen fertiliser applications and losses of nitrate to drainage. Therefore lower concentrations observed in the Lough Erne catchment in comparison to the Lough Neagh catchment are to be expected given the lower level of agricultural production in the Erne. However high rates of soil denitrification result in nitrate concentrations in the Erne rivers being even lower than expected and this appears to be commonplace in many of the rivers to the west of Northern Ireland. AESD are currently developing a model for predicting nitrate concentrations in surface water within Northern Ireland. There is a need therefore, to further develop and validate this model as a tool to improve the quantification of the processes governing nitrate losses within Northern Ireland and to predict the potential impact of any future changes in the use of nitrogen by agriculture.

Conclusion 7: Manure Application Rates within NVZs. Further assessment should be carried out to examine whether a case can be made to the European Commission to justify permitting higher manure nitrogen application rates than the specified amount of 170 kg N / ha / yr in NVZs in Northern Ireland. This may be permissible under Annex III, Section 2b of the Directive, which refers to exceptions for soils with an 'exceptionally high denitrification potential'. This option, however, will have to be viewed in context with other national and international obligations on emissions to air.

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