A WATER QUALITY STUDY OF LOUGH GOWNA

Presented for the Degree of Master in Science (Environmental Protection) in Sligo Regional Technical College.

By

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Submitted to the National Council for Educational Awards June 1996.

Acknowledgement

I wish to acknowledge the assistance I received from the following people in preparing this thesis; the staff of the Northern Regional Fisheries Board at Ballinagh, Co. Cavan.; Maeve Quinn, E.P.A., Monaghan; Matt Morgan and John Gibbons, E.P.A., Athlone; the Sanitary Services and Environmental Department staff of Cavan County Council; my colleagues in Longford County Council, particularly Helen Murtagh, typist; Mr. Trevor Champ, Central Fisheries Board and my tutor, Mr. Jim Clancy, Forbairt.

Abbreviations

A.F.F. -	An Foras Forbartha
C.S.O. -	Central Statistics Office
E.C. -	European Community now European Union
E.P.A. -	Environmental Protection Agency
G.W.S. -	Group Water Scheme
N.D. -	Not Detectable
R.S.W.W. -	Regional Water Supply Scheme.
S.S. -	Sewerage Scheme
T.K.N. -	Total Kjeldahl Nitrogen
W.S. -	Water Supply

A Water Quality Study of Lough Gowna

A. Brady

Abstract

Lough Gowna, located on the borders of Counties Cavan and Longford is an important coarse fish angling lake, and also has stocks of brown trout. The lake attracts thousands of British, European and local anglers and has been the venue for the All Ireland Course Angling Competition. Lough Gowna is popular for swimming, water skiing and power boat racing. The lake is also used for abstraction of public water supplies by Longford and Cavan County Councils.

Suitable water quality criteria to protect the above mentioned uses are;

(i) EC (Quality of Salmonid Waters) Regulations, 1988.

(ii) EC (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989.

The water quality monitoring data complied by Cavan and Longford County Councils, the E.P.A. and the Northern Regional Fisheries Board is reviewed and compared with studies carried out in the 1970's and 1980's by An Foras Forbartha. High phosphorus and chlorophyll *a* concentrations and very low transparency levels together with the dominance of blue-green algae in the phytoplankton indicate the lake is eutrophic. Stratification of the lake in the summer months gives rise to severe deoxygenation in the hypolimnion.

"Excessive" and "permissible" annual phosphorus loadings for Lough Gowna were calculated using Vollenweider's equation (Vollenweider 1976). The "permissible" annual loading of phosphorus is 174 mg P m^{-2} yr^{-1} and the "excessive" annual loading is 349 mg P m^{-2} yr^{-1}; this corresponds to 2.24 tonnes P and 4.5 tonnes P respectively. The actual orthophosphorus loading is 527 mg P m^{-2} yr^{-1}. This is calculated from average lake orthophosphorus concentrations using another equation by Vollenweider (Vollenweider 1980).

A large scale fish kill in Lough Gowna in July 1993 was caused by deoxygenation due to eutrophication and resulted in 99.9% perch fry mortality. This prompted a trial in 1994 using barley straw to inhibit the growth of algae in the lake. The results of the trial were inconclusive as the straw failed to decompose completely and was not replaced with fresh straw. There was some evidence to indicate the algae in the treated section of the lake were under stress.

As there are no direct industrial or sewage discharges in the catchment area , agricultural wastes are the most likely cause of eutrophication in Lough Gowna. Controlling disposal of farm wastes under Section 12 of the Local Government (Water Pollution) Act, 1977 should help to limit the impact of agricultural activity on Lough Gowna. A phosphorus budget for the lake should be prepared to establish the extent to which farm wastes and the use of artificial fertilisers should be controlled.

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Introduction

The aim of this water quality study of Lough Gowna is to review its present status from available data and information and thereby to determine ways in which quality could be improved. Water quality monitoring data was provided by Cavan County Council, the Environmental Protection Agency, the Northern Regional Fisheries Board and by the author for Longford County Council using Standard Methods (APHA, 1980).

The beneficial uses of the lake, which include abstraction of drinking water, coarse and game fishing, water skiing and swimming, are examined, and water quality criteria to protect these uses are described. The trophic status of the lake is determined from recent water quality monitoring data and this is compared to studies carried out in the 1970's and 1980's. In addition, the phosphorus loading on the lake is calculated and the likely effects of this on algae levels is examined.

In 1994 a trial was carried out using barley straw to inhibit the growth of algae and the results of this experiment are discussed.

Finally, a number of conclusions are made regarding the water quality of the lake, the likely sources of pollution and ways of reducing their effects.

1. Description of Catchment

1.0 Description of Catchment and Topography

Lough Gowna is located on the borders of counties Cavan and Longford (Figure 1) Grid Reference N30 90. It is a medium sized lake with a total area of 12.9 km^2. The lake is part of the Erne catchment. The surrounding topography is drumlin and this accounts for the complex outline of the lake. The catchment area of the lake and River Erne upstream of Lough Gowna is 263 km^2.

Lough Gowna is divided into two basins. The northern section, which has a maximum length of 3 km and maximum depth of 12 metres, flows into the southern section which has a maximum length of 4 km and a maximum depth of 10 m. The lake water flows east from the southern section into the River Erne. A considerable amount of the shoreline is wooded in the southern section but the land surrounding the northern section is generally open.

1.1 Geology

The underlying geology of the area features Ordovician bedrock in the northern and Silurian bedrock in the southern section, the junction between the two rock types being located just north of Dernaferst. The geology of the southern extremities of the lake catchment is carboniferous limestone.

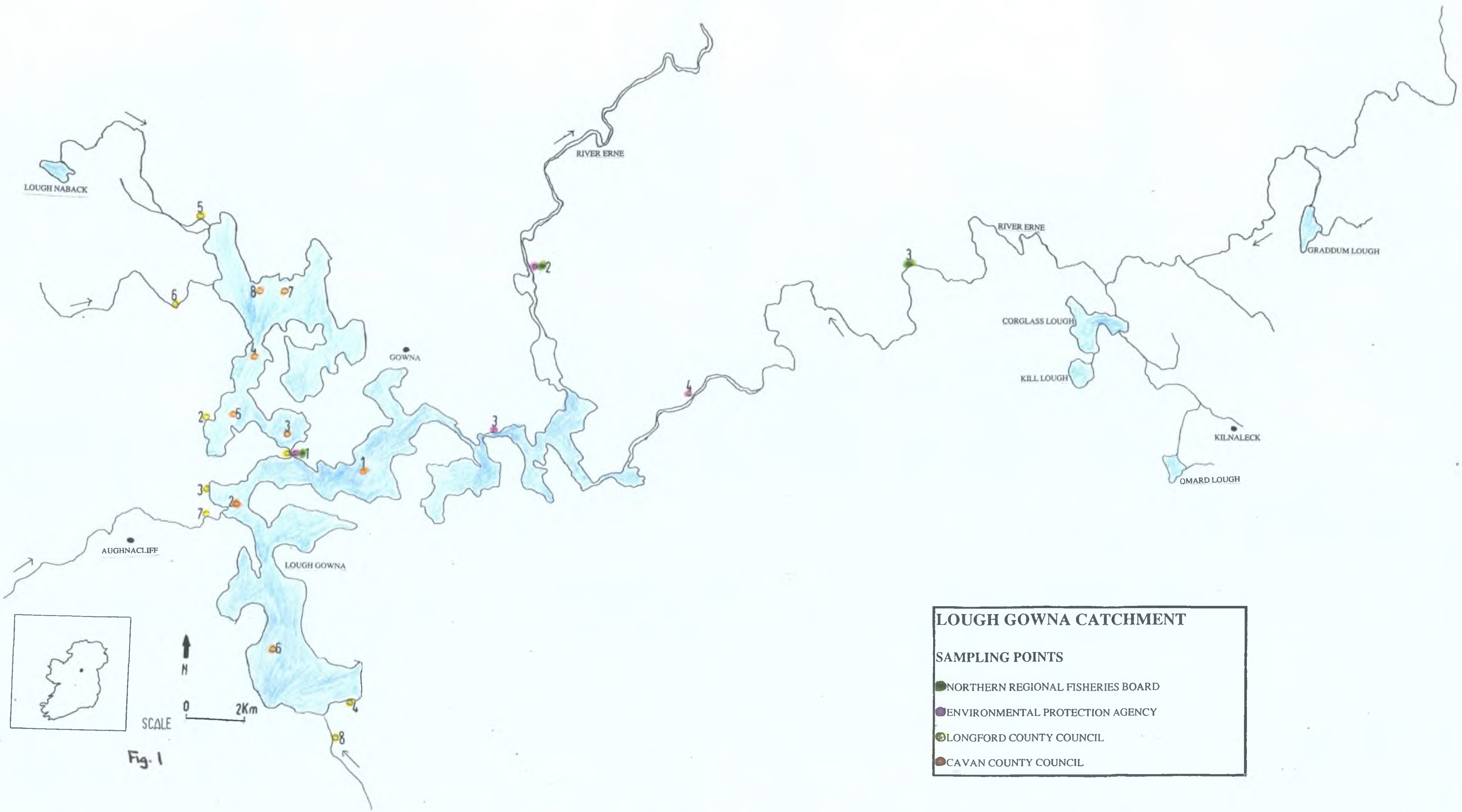

LOUGH NABACK
RIVER ERNE
RIVER ERNE
GRADDUM LOUGH
CORGLASS LOUGH
KILL LOUGH
KILNALECK
OMARD LOUGH
GOWNA
AUGHNACLIFF
LOUGH GOWNA
N
0
2Km
SCALE
LOUGH GOWNA CATCHMENT
SAMPLING POINTS
NORTHERN REGIONAL FISHERIES BOARD
ENVIRONMENTAL PROTECTION AGENCY
LONGFORD COUNTY COUNCIL
CAVAN COUNTY COUNCIL

Fig. 1

Soil types also differ in the two parts of the catchment; to the north gleys predominate with acid brown earths while, to the south, reclaimed podzols are the principal soils and are associated with gleys.

1.2 Botany

The relatively low alkalinity status of the lake is shown by the occurrence of two plants, water lobelia, *Lobelia dortmanna*, and quillwort, *Isoetes lacustris,* which grow in the northern section at Arnaghan (A.F.F. 1981). A stonewort, *Nitella flexilis* has limited distribution. Peat bog occurs in places on the north and east shore, as at Scrabby Bridge and west of Dernaferst, where an unusual bulrush, *Typha angustifolia,* and a usually upland fern, *Thelypteris limbosperma* grow. Elsewhere the shores are stony, either sloping on the edges of drumlins or flat and open in the east.

1.3 Areas of Scientific Interest

Areas of scientific interest in the catchment include Lough Naback, which is of ecological and zoological interest (AFF, 1981). It is an upland acid lake with char. Char is a northern fish which survives in oligotrophic waters because of a lack of competition from other species. They are real lake fish and their eggs float in the plankton until they hatch. Also, Erne Head at Lough Gowna is of botanical and ecological interest. It is located on the south-eastern shore of Lough Gowna and is predominantly an oak woodland, with trees reaching a height of 25 m. The understorey is mainly beech - a few large beeches about 30 m high are found - with some holly and hazel. The ground flora includes *Blechnum spicant* (hard fern),*Vaccinium myrtilis*, (Bilberry), *Rubus fruticosus* (Blackberry), *Hedera helix* (ivy), *Luzula sylvatica* (Wood Rush), *Thuidium amariscinum* and *Rhytidiadelphus triquetrus* (mosses) and a little *Calluna vulgaris* (ling).

The western edge of the wood is planted with spruce and at the southern edge there is a small grove of Lawson's Cypress, a few pines and western hemlock.

Between the roadway and the woodland is a small area of raised bog which adds to the ecological diversity. As this is the only natural woodland of any size on the Longford shore of Lough Gowna, and is one of the few areas of oak woodland in the county, it is of considerable importance.

The Lough Gowna region is of ornithological interest, as the whole area is a wintering site for wildfowl species. A rich variety is present and numbers of goldeneye (up to 50), shoveler (80) and pintail (10) are noteworthy. The main species are mallard (200), tufted duck and red-breasted merganser, but the more noticeable species in summer are the black-headed gulls nesting in colonies, the great crested grebes and ringed plover.

1.4 Agriculture

In the Longford end of the catchment, two thirds of the farms specialise in beef production and a quarter in dairying (CSO, 1991). In the Cavan area there is an equal proportion specialising in dairying (44%) and beef production (42%); the remainder of farms consist of mixed grazing livestock. There are approximately 44,000 cattle in the catchment, giving a stocking density of 167 cattle/km^2. This is a significant increase from 1975 statistics (C.S.O.,1975), which showed this region had a stocking density of 117 cattle/km^2. One possible reason for this is that farmers keep more cattle to avail of headage payments from the EC. There are approximately 16,000 sheep in this catchment and 5,200 hectares are under silage.

Pig production is an important element of agricultural activity particularly in County Cavan. The tendency is for pig production to be concentrated in a relatively small number of large units. There are ten piggeries in the catchment in Co. Cavan and three in Co. Longford. There are no tillage farms in the area.

As a result of the large dependence on livestock husbandry in the catchment, there is considerable potential for organic waste from this source to reach waterways.

1.5 Population

The population of the catchment is approximately 7,200. That part of the catchment in Co. Cavan has a population of 4,500 and Co. Longford has 2,700. There are three villages in the catchment.

Village	Population
Gowna	121
Kilnaleck	241
Aughnacliffe	50

The population density is 28 people/km^2 which is lower than the national average. None of the islands in Lough Gowna are inhabited.

1.6 Feeder Streams

There are fourteen identified surface streams entering the lake; the River Erne is the largest, and the remaining thirteen have relatively small catchments.

The River Erne rises in the Slieve Glash area of County Cavan and initially flows west into Lough Gowna before flowing north where it connects Lough Oughter with Upper and Lower Lough Erne.

2. Beneficial Uses of theLake

2.0 Abstractions

An Foras Forbatha carried out a national survey of abstractions and discharges in 1977 (AFF, 1977). The survey identified and mapped (Fig. 2) all abstractions and discharges to water in excess of $5m^3$ /day (Table 1).

The abstractions and discharges were classified as either (a) public bodies and (b) industry and others. Public Bodies means local and sanitary authorities with statutory functions in respect of water supply and sewerage. Group water schemes were included in this category. All other abstractions and discharges were included under the second heading. The data gathered in the AFF survey is presented in Tables 1 and 2 and the most recent information on abstractions and discharges is shown in Tables 3 and 4.

The four largest abstractions are for public water supply schemes; two are abstracted directly from Lough Gowna, one from Omard Lough and one from Lough Naback.

Kilnaleck W.S.

Kilnaleck water supply is abstracted at a rate of 250 m^3/day from Omard Lough. It serves a population of 321 people and the water is treated by pressure filtration and chlorination.

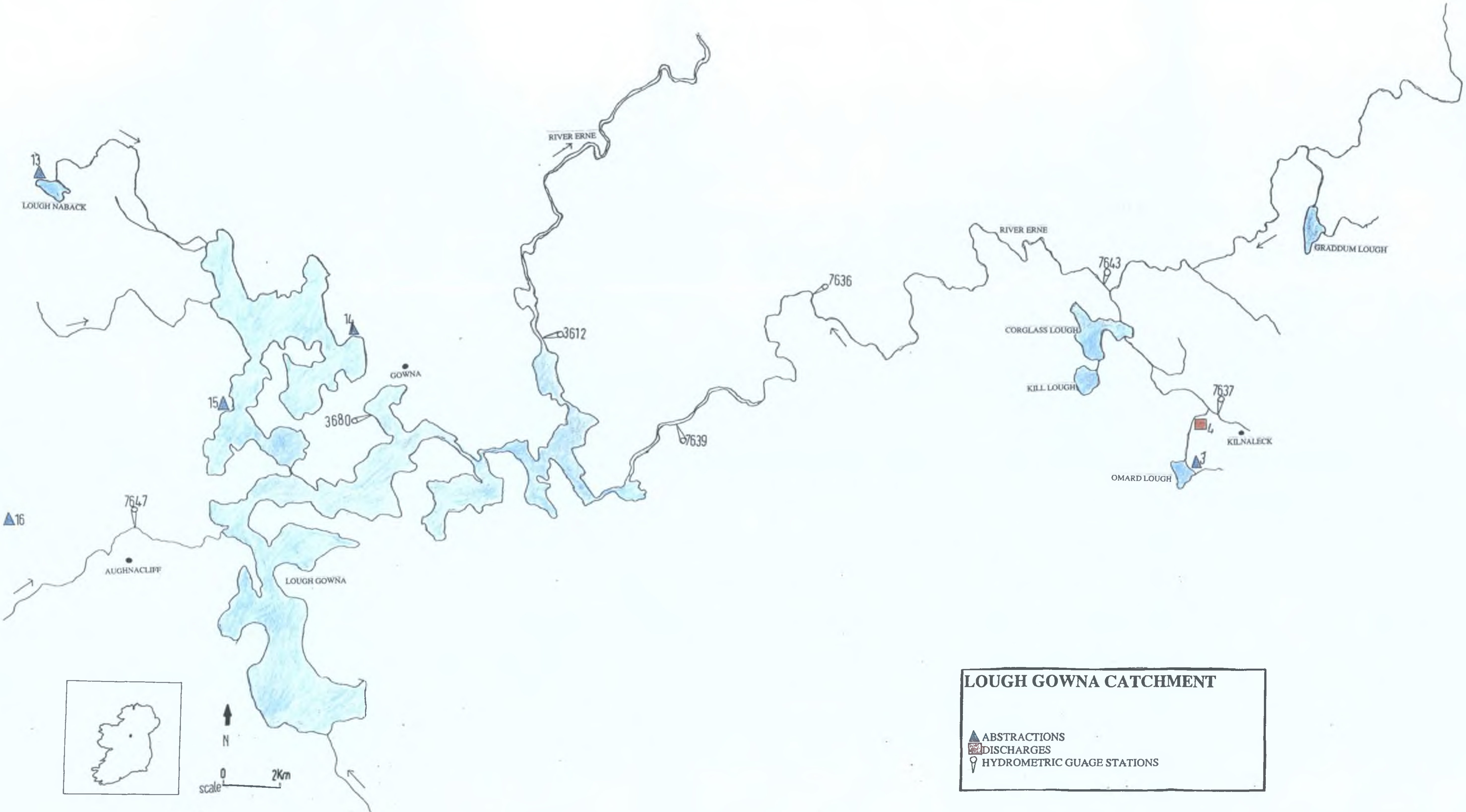

13
LOUGH NABACK
RIVER ERNE
RIVER ERNE
7636
7643
GRADDUM LOUGH
CORGLASS LOUGH
KILL LOUGH
7637
4
KILNALECK
3
OMARD LOUGH
14
3612
GOWNA
15
3680
7639
7647
16
AUGHNACLIFF
LOUGH GOWNA
N
scale
0
2Km
LOUGH GOWNA CATCHMENT
ABSTRACTIONS
DISCHARGES
HYDROMETRIC GUAGE STATIONS

Fig. 2

Arva W.S.

Lough Naback provides 164 m^3/day of water to a population of 500 people. Treatment consists of pressure filtration and chlorination.

Gowna W.S. (Cavan Co. Co.)

This water supply is abstracted from Lough Gowna. As in the case of Lough Naback, treatment consists of pressure filtration and chlorination. Daily usage is 182m^3/day and the population served is 300 people.

At the time of writing, proposals are being finalised for the Lough Gowna Regional Water Supply Scheme which will also be sourced from the lake. The region under consideration covers an area of 493 km^2 and stretches from Lough Gowna in the south to the Cavan/Fermanagh border in the north. The limits to the west are the Cavan/Longford and Cavan/Leitrim borders while the eastern boundary follows a line through the towns of Butlersbridge and Ballinagh to the west of Cavan Town. The expected population to be served is 10,120 people. The volume to be abstracted is 13,500 m^3/day and the proposed treatment will be coagulation/flocculation with either settlement or dissolved air floatation followed by rapid gravity filtration.

Lough Gowna R.W.S.S. (Longford Co. Co.)

Water is abstracted from Lough Gowna and treated by flocculation/coagulation, sedimentation and filtration. A total of 700 m^3/day is abstracted from the lake at Cornadrung and 5,400 people are supplied.

2.1 Waste Discharges

Of the five discharges existing at the time of the original survey by An Foras Forbartha (Table 2), only one still exists. That is the discharge from Kilnaleck Sewerage Scheme. Treatment here consists of a trickling filter and the effluent is discharged to a tributary stream of the River Erne. The discharged organic load is 2 kg BOD/day (Table 3).

The other four discharges were from Killeshandra Co-op (now Lakeland Dairies) Branch Creameries. At that time milk was collected, cooled and stored at these premises and then tankered to the Co-op for processing. The water used for washing of plant and premises was discharged to rivers and streams. Now these premises are only used as collection points where milk is transferred from the farmers tanks to the larger milk tankers, thus eliminating the need for washing of plant, etc. There are no licenced industrial effluents discharging into the catchment.

Table 1 - Water abstractions from Lough Gowna catchment (A.F.F., 1977)

Ref. No. of Abstraction	Name of Abstractor	Abstraction Point	Grid Reference	Type of Source	Quantity (m^3/day)
2 b	Crosserlough G.W.S.	Graddam Lough	N46 93	Lake	264
3	Kilnaleck W.S.	Omard Lough	N435 900	Lake	250
13	Arva W.S.	Lough Naback	N247 950	Lake	164
14	Gowna W.S. (Cavan Co. Co.)	Lough Gowna	N297 921	Lake	182
1	Crosskeys Creamery	Crosskeys	N479 970	Bore	23
5	Carrigan Creamery	Carrigan Bridge	N393 932	River	10
7	Grousehall Creamery	Kilsaran	N366 908	Stream	10
8	Grousehall Creamery	Kilsaran	N365 910	Bore	13
15	Lough Gowna R.W.S.S. (Longford Co. Co.)	Lough Gowna	N278 912	Lake	270
16	Fostra G.W.S.	Fostra	N238 887	Spring	45

Table 2 - Effluent discharges to Lough Gowna catchment (A.F.F., 1977)

Ref. No. of Discharges	Name of Scheme	Discharge Point	Grid Reference	Receiving Water	Quality m^3/day
4	Kilnaleck S.S.	Kilnaleck	N443 906	Stream	100
2	Crosskeys Creamery	Crosskeys	N480 967	Stream	23
2A	Drumcrow Creamery	Drumcrow	N432 972	River	5
4A	Kilnaleck Creamery	Kilnaleck	N443 906	River	15
6	Carrigan Creamery	Carrigan	N392 933	River	10
9	Grousehall Creamery	Kilsaran	N366 908	Stream	23

Table 3 - Water abstractions from Lough Gowna catchment - 1996

Ref. No of Abstraction	Name of Abstractor	Abstraction Point	Grid Reference	Type of Source	Quantity (m^3/day)
3	Kilnaleck W.S.	Omard Lough	N435 900	Lake	250
13	Arva W.S.	Lough Naback	N247 950	Lake	164
14	Gowna W.S.	Lough Gowna	N297 921	Lake	182
15	Gowna R.W.S.S.	Lough Gowna	N276 911	Lake	700
16	Fostra G.W.S.	Fostra	N238 887	Spring	45

Table 4 - Effluent discharges to Lough Gowna catchment - 1996

Ref. No of Discharge	Name of Scheme	Discharge Point	Grid Reference	Receiving Water	Quantity (m^3/day)
4	Kilnaleck S.S	Kilnaleck	N443 906	Stream	100

2.2 Angling

Lough Gowna

Game - Brown Trout

Coarse - Pike, Perch, Roach, Rudd, Bream hybrids and Eels.

Perhaps the first lake to attract British Cyprinid Anglers to Ireland after the war (early 1950's). Lough Gowna is a 'match' water and has been the venue for the 'All Ireland Coarse Angling Competition' for a number of years.

Lough Naback

Game - Brown trout, Char

Coarse - Roach, Perch.

The lake is the only one in the region with a resident char population.

Corglass Lake

Game - None.

Coarse - Rudd, Pike, Perch, Roach, Bream hybrids and Eels.

Graddum Lough

Game - None

Coarse - Pike, Perch, Roach, Rudd, Bream hybrids and Eels.

This lake is not fished extensively although angling seems to be good. Some tourist anglers.

Omard Lough

Game - None

Coarse - Pike, Perch, Roach, Rudd, Bream hybrids and Eels.

Kill Lough

Game - None

Coarse - Pike, Perch, Roach, Rudd, Bream hybrids and Eels.

River Erne, Kilnaleck Stream, Aughnacliffe Stream.

Game - Brown Trout

Coarse - Pike, Perch, Roach and Eels.

2.3 Water Sports

Lough Gowna is popular for power boat racing and is one of the competition sites for speed boats in the "King of Clubs" Match Series. It is also used for water skiing and Dernaferst and Dring are popular sites for swimming with picnic areas and car park.

3. Water Quality Criteria and Standards

3.0 Introduction

Criteria are designed to protect the desirable uses of water. The user with whom we are most concerned is Man, and his use of water for drinking and recreational purposes. Other users of water that concern us include fish which live within the water body and the organisms upon which they depend for food. Water quality criteria are not intended to offer the same degree of safety for survival and propagation at all times to all organisms. Before going on to examine which criteria and standards are used we must first look at some important definitions.

Criteria: a scientific requirement on which a decision or judgment may be based concerning the suitability of water quality to support a designated use.

Standards: legally prescribed limits of pollution which are established under a statutory authority.

The waters of the Lough Gowna catchment are used for many purposes and the requirements of each of these, in terms of water quality, must be taken into account. The standard set for each water quality parameter must meet the criteria of the most sensitive beneficial use. In general, the standards set for salmonid waters are the most stringent and if these standards are met the water is suitable for all other uses including abstraction for drinking water.

Since water is abstracted for public water supplies from three lakes in the catchment and trout are present in some of the watercourses, the criteria to be used for water quality are EC (Quality of Salmonid Waters) Regulations, 1988 and EC (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989. However, Lough Gowna and the other watercourses in the catchment are not designated under the E.C. (Quality of Salmonid Waters) Regulations, 1988.

3.1 E.C. (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989.

The Surface Water Regulations apply to surface fresh water sources from which drinking water is, or is intended to be, abstracted and supplied for public use. The two purposes of the regulations are:

(i) to ensure that surface water abstracted for use as drinking water reaches specified standards and is given an appropriate level of treatment before being put into public supply, and

(ii) to improve, where necessary, the quality of rivers or other surface water sources used for abstractions.

They are concerned with the quality of raw water and have less direct implications for public health and broader emphasis on environmental management. According to the regulations, a Sanitary Authority must classify surface water in accordance with specified quality standards into three categories, A1, A2 and A3 which correspond to specified and increasingly elaborate standard methods of treatment as follows:

A1 - Simple physical treatment and disinfection, e.g. rapid filtration and disinfection.

A2 - Normal physical treatment, chemical treatment and disinfection, e.g. pre-chlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination).

A3 - Intensive physical and chemical treatment, extended treatment and disinfection, e.g., chlorination to break-point, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination).

The regulations state that surface water will be deemed to comply with the specified quality standards where;

(a) 95% of samples comply with the relevant standards, and

(b) in the case of the 5% of the samples which do not comply:

(i) the water does not deviate from the standards by more than 50%, except in the cases of temperature, pH, dissolved oxygen and the microbiological parameters.

(ii) there is no resultant danger to public health and,

(iii) no two consecutive samples deviate from the specified quality standards.

3.2 E. C. (Quality of Salmonid Waters) Regulations, 1988.

The regulations make a distinction between salmonid waters (i.e. for species such as salmon, trout, char and whitefish) and cyprinid waters, (i.e. for species such as pike, perch and eel) based on their ability to support, or become capable of supporting, fish belonging to these species. Water quality standards are set for salmonid and cyprinid waters, with the higher standards applying to salmonid waters.

Copies of both regulations are presented in Appendix F and G.

3.3 The More Important Water Quality Parameters.

Dissolved Oxygen

Dissolved oxygen is one of the most important indicators of purity of waters for two reasons:

1. It gives information on the amount of biodegradable organic pollution.
2. It indicates the suitability of water for fish.

Fish and in particular game fish are the aquatic organisms most sensitive to low dissolved oxygen levels. Trout require at least 7 mg/l dissolved oxygen, but some coarse fish can survive at levels as low as 1-2 mg/l D.O. At low oxygen levels fish have problems with:

1. Respiration.
2. Reproduction.
3. Defense against predators.
4. Lower resistance to disease and injury.

Toxicity of some substances to fish can increase at lower oxygen levels. The standard set for salmonid water is at least 9 mg/l dissolved oxygen in 50% of samples.

Biochemical Oxygen Demand

The biochemical oxygen demand test is one of the most widely used parameters in the measurement of organic pollution. When organic matter is discharged into a watercourse it serves as a food source for bacteria. The B.O.D. of a water is the amount of dissolved oxygen taken up by the bacteria in degrading oxidisable matter in the sample, measured after 5 days incubation in the dark at 20°C. The B.O.D. is simply the amount by which the D.O. level has dropped during the incubation period. The standard for B.O.D. required for salmonid fisheries and water for abstraction of drinking water is not more than 5 mg/l .

Ammonia

Ammonia is naturally present in surface waters, though in very small amounts, normally as a result of microbiological activity which causes the reduction of nitrogen-containing compounds. From the viewpoint of human health, the significance of ammonia is high because it indicates the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms. High ammonia levels also interfere with chlorination processes in water treatment. The formation of chloramine compounds between the added chlorine and the ammonia present in the water necessitates an increased use of chlorine if disinfection efficiencies are to be maintained.

Ammonia can be toxic to fish; the toxic effect is due to unionised NH_3, the concentration of which increases with rising pH and temperature.

To protect salmonid waters the standard set is $\leq$ 0.02mg/l NH_3. The standard for water abstracted for drinking purposes is 0.2 mg/l NH_4^+ for A1 water and 1.5 mg/l NH_4^+ for A2 water.

Oxidised Nitrogen

Nitrate - Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia. Of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. There is no standard for nitrate levels in the E.C. (Quality of Salmonid Waters) Regulations. The standard set for water intended for abstraction of drinking water is 50 mg/l NO_3.

Nitrite - Nitrite exists normally in very low concentrations and, even in waste treatment plant effluents, levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH_3) or more oxidised (nitrate; NO_3) forms. Waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.01 mg/l N. Values greater than this may indicate sewage pollution.

There is no limit set for nitrite in the E.C. (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations. For salmonid waters the limit is $\leq$ 0.05mg/l NO_2.

Phosphates

Phosphorus occurs widely in nature in plants, in microorganisms, in animal wastes. It is a commonly used agricultural fertiliser and is a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface waters.

The significance of phosphorus is principally in regard to the phenomenon of eutrophication of lakes and, to a lesser extent, rivers. Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variations of great magnitude and related problems.

There is considerable discussion as to the availability of the various forms of phosphorus for the growth of algae although it is considered that orthophosphate is the most readily used form.

In the E.C. (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, the limit set for phosphates is 0.5 mg/l P_2O_5 for A1 water and 0.7 mg/l P_2O_5 for A2 water. There is no standard set for salmonid waters.

4. Water Quality

4.0 Water Quality Monitoring

Water quality of rivers and lakes in the catchment is monitored by Cavan and Longford County Councils, the E.P.A. and the Northern Regional Fisheries Board. The results of monitoring for the last number of years are presented in Appendix A to E. Sampling points are listed in Table 5, and location of sampling points are shown in Figure 1.

Table 5. List of sampling points

Agency	Sampling Point
Environmental Protection Agency	1. Dernaferst Bridge
	2. Sallaghan Bridge
	3. Scrabby Bridge
	4. Kilsoran Bridge
Northern Regional Fisheries Board	1. Dernaferst Bridge
	2. Sallaghan Bridge
	3. Bruskey River
Longford County Council	1. Dernaferst Bridge
Lake	2. Cornadrung
	3. Dunbeggan
	4. Dring
Feeder Streams	5. Stream at Rosduff (from Lough Naback)
	6. Stream at Cornadrung
	7. Stream at Dunbeggan
	8 Stream at Dring

4.1 Chlorophyll *a* and Transpaency

Chlorophyll *a* concentrations showed a steady increase from 1992 to 1995 (Fig. 3) mean chlorophyll *a* levels ranged from 20.5 mg m^{-3} to 88.7 mg m^{-3}.

Water transparency remained very low over the same time period (Fig. 3) due to the high chlorophyll *a* levels. The maximum transparency recorded during this time was only 2 metres and the mean transparency varied between 0.56 metres at Station 1 and 1-2 metres at Station 4.

4.2 Total Phosphorus and Orthophosphates

Mean total phosphorus and orthophosphates measured by the Northern Regional Fisheries Board at Dernaferst Bridge between 1985 and 1995 showed a steady increase from 1990 onwards (Fig. 4) from 0.005 mg/l P to 0.025 mg/l P for orthophosphates and from 0.051 mg/l P to 0.128 mg/l P for total phosphorus. There was also an upward trend in mean orthophosphate levels measured by Cavan County Council (Fig. 5). The maximum orthophosphate concentration recorded was 0.053 mg/l P at Station 4 (Table A4) but the mean levels were between 0.017 mg/l P and 0.035 mg/l P.

4.3 Ammonia

Mean ammonia concentrations ranged between 0.032 mg/l N and 0.089 mg/l N during 1992 to 1995. The maximum recorded level was 0.2 mg/l N at Station 7 in 1993 (Fig. 6). These concentrations are in excess of the standard of <0.02 mg/l NH_3 set for salmonid waters.

4.4 Dissolved Oxygen.

The dissolved oxygen concentration of the surface layers of the lake varied between a minimum of 83% saturation and a maximum of 161% saturation but in general the mean concentrations were between 96% and 124% saturation (Fig. 7.)

4.5 Stratification

Thermal stratification is usually evident in Lough Gowna during the summer months. This gives rise to a lowering of oxygen levels to below 50% saturation in the hypolimnion (Figs. 8 to 11) In July 1992 the oxygen concentration at a depth of 10 m. was only 2% saturation. In July 1994 it was 19% saturation at 9 m. At other times of the year the deeper parts of the water column are well oxygenated due to complete mixing in the lake.

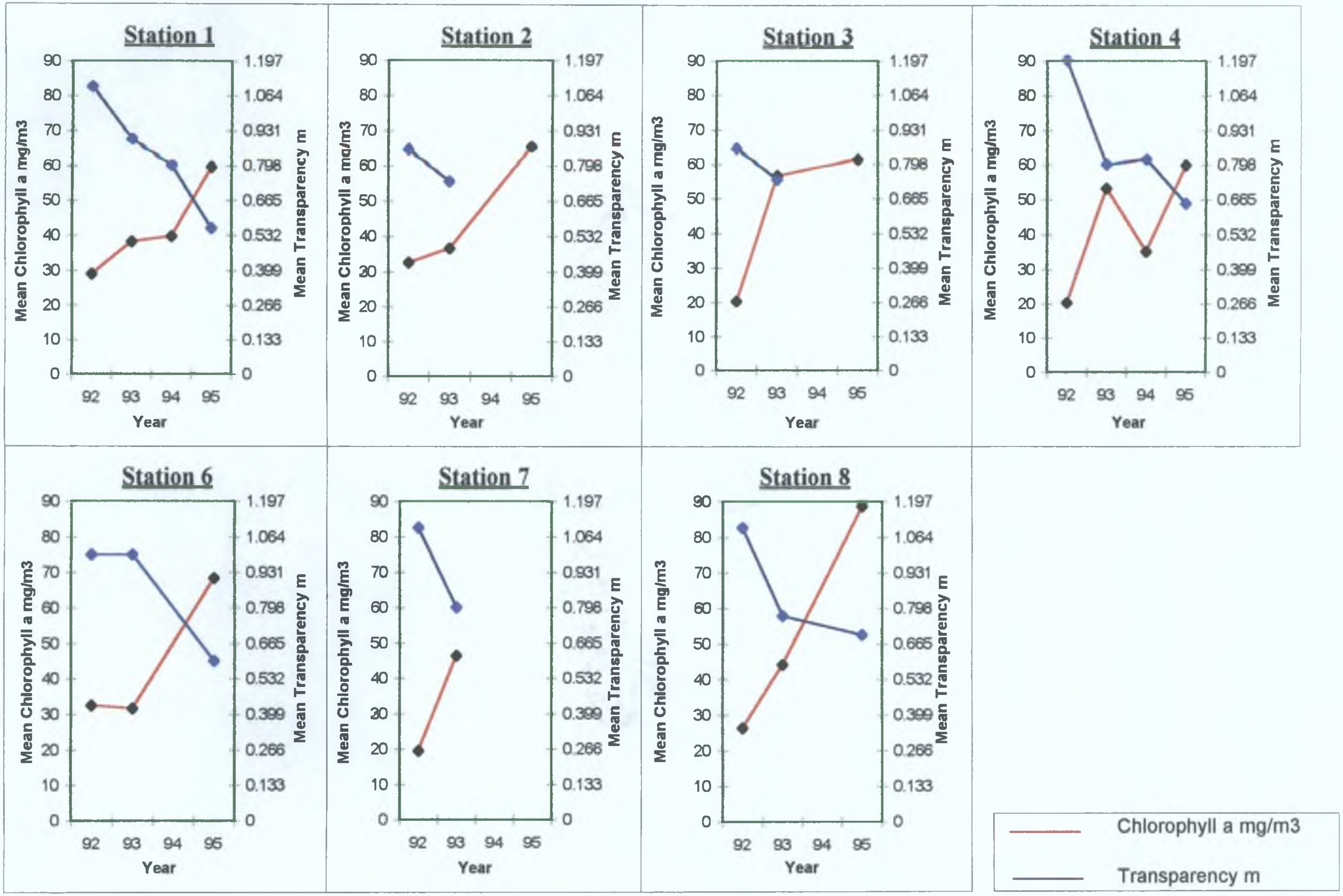


Fig. 3 Mean chlorophyll *a* mg/m3 v mean transparency m

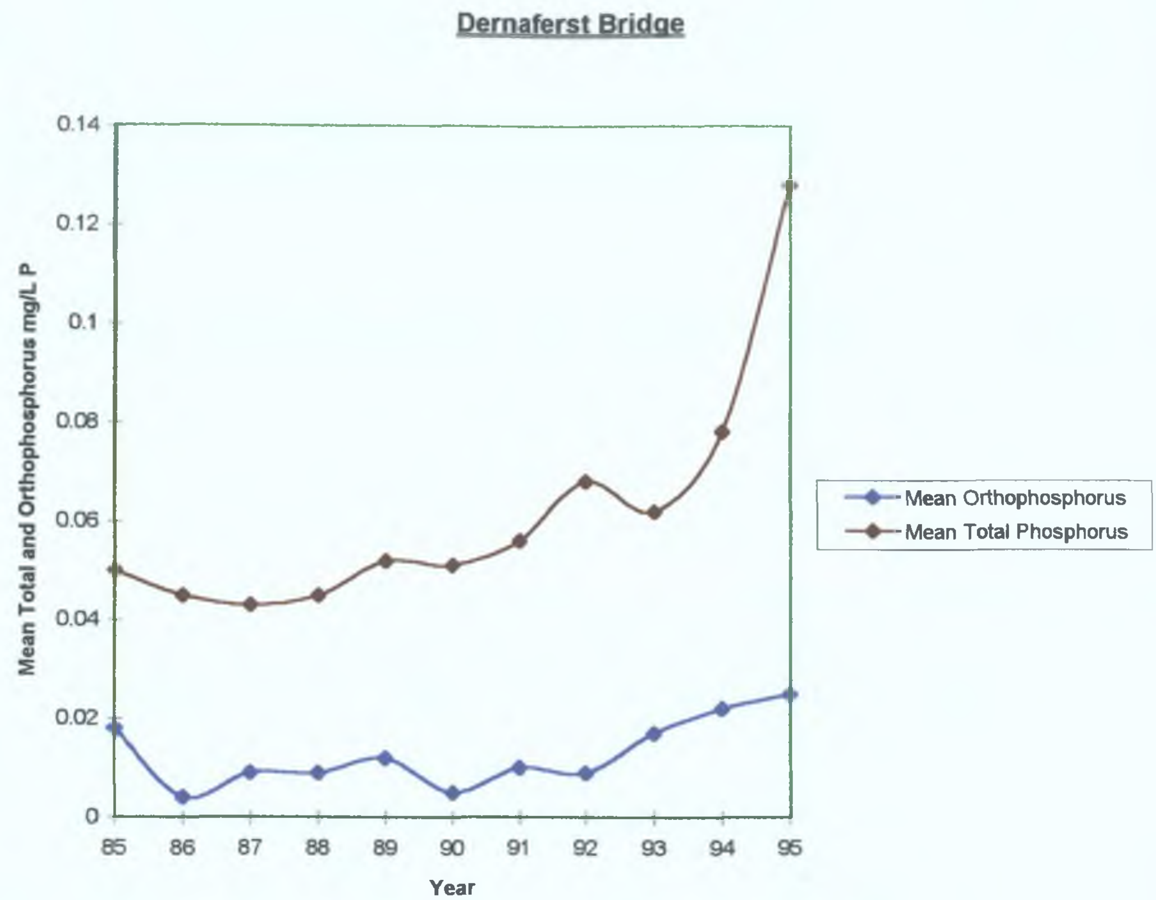


Fig. 4 Mean total and orthophosphorus concentrations at Dernaferst Bridge (Northern Regional Fisheries Board) .

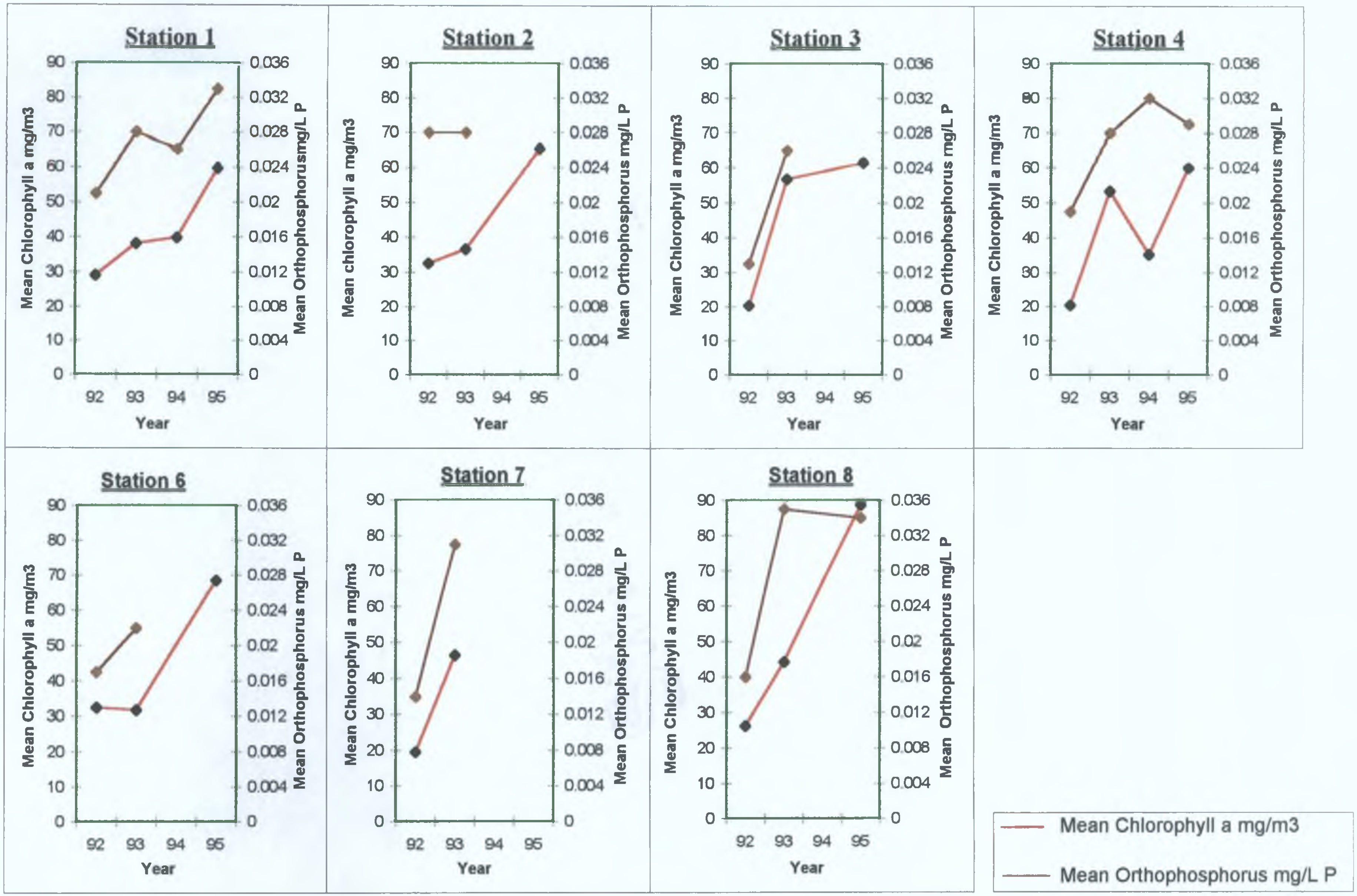


Fig. 5 Mean chlorophyll *a* mg/m3 v mean orthophosphorus mg/L P

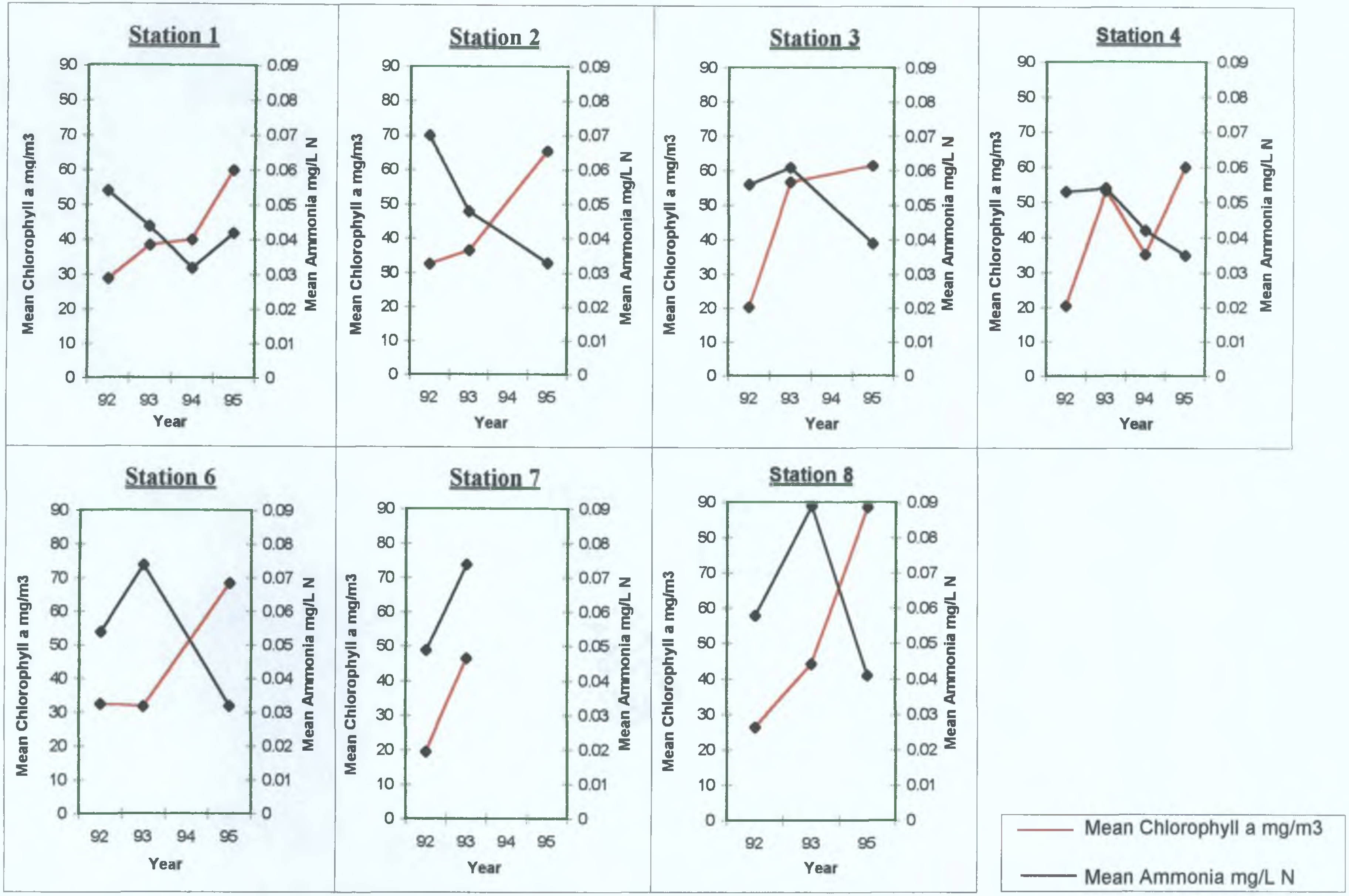


Fig. 6 Mean chlorophyll *a* mg/m3 v mean ammonia mg/L N

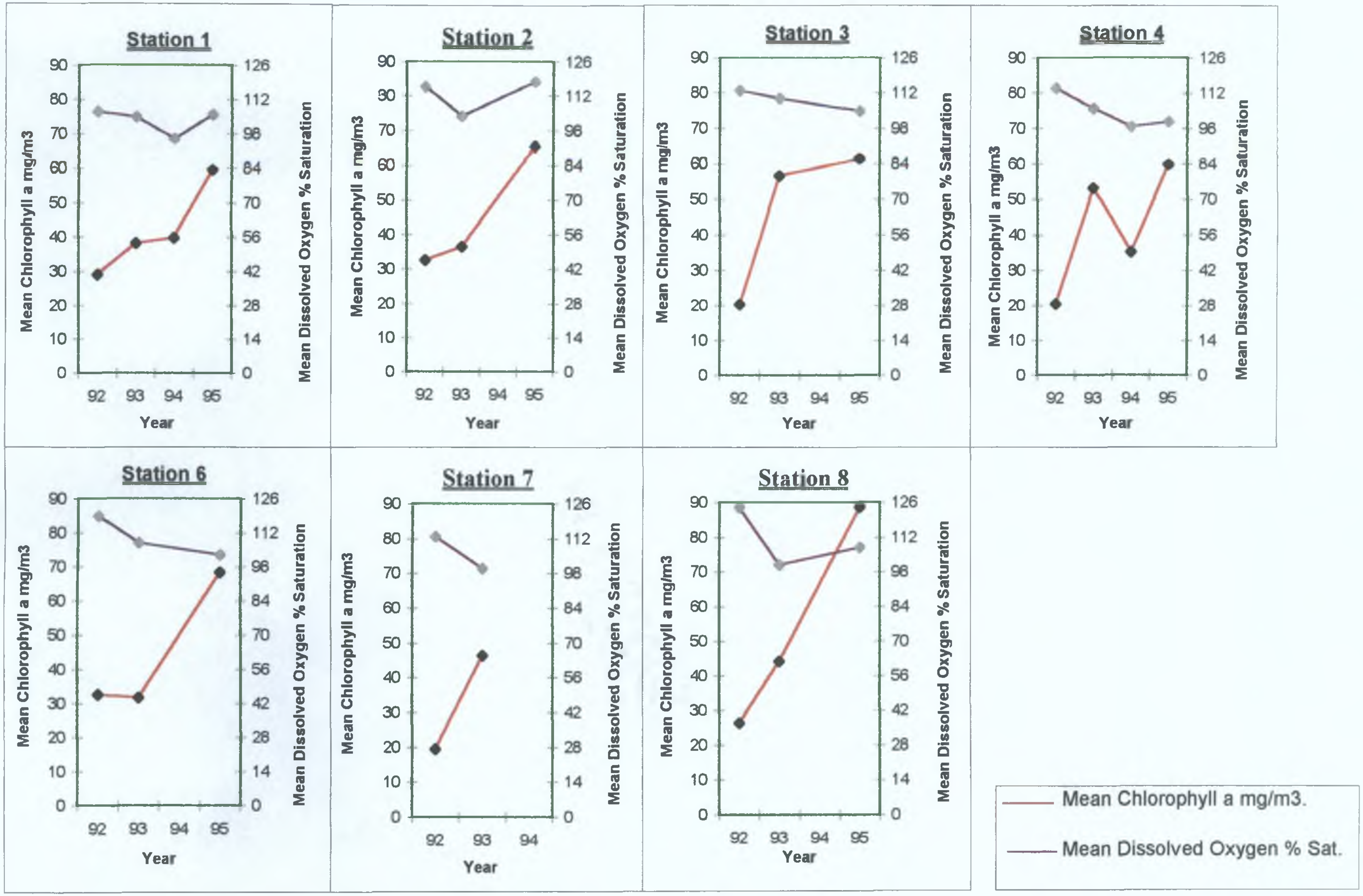


Fig. 7 Mean chlorophyll *a* v mean dissolved oxygen % saturation

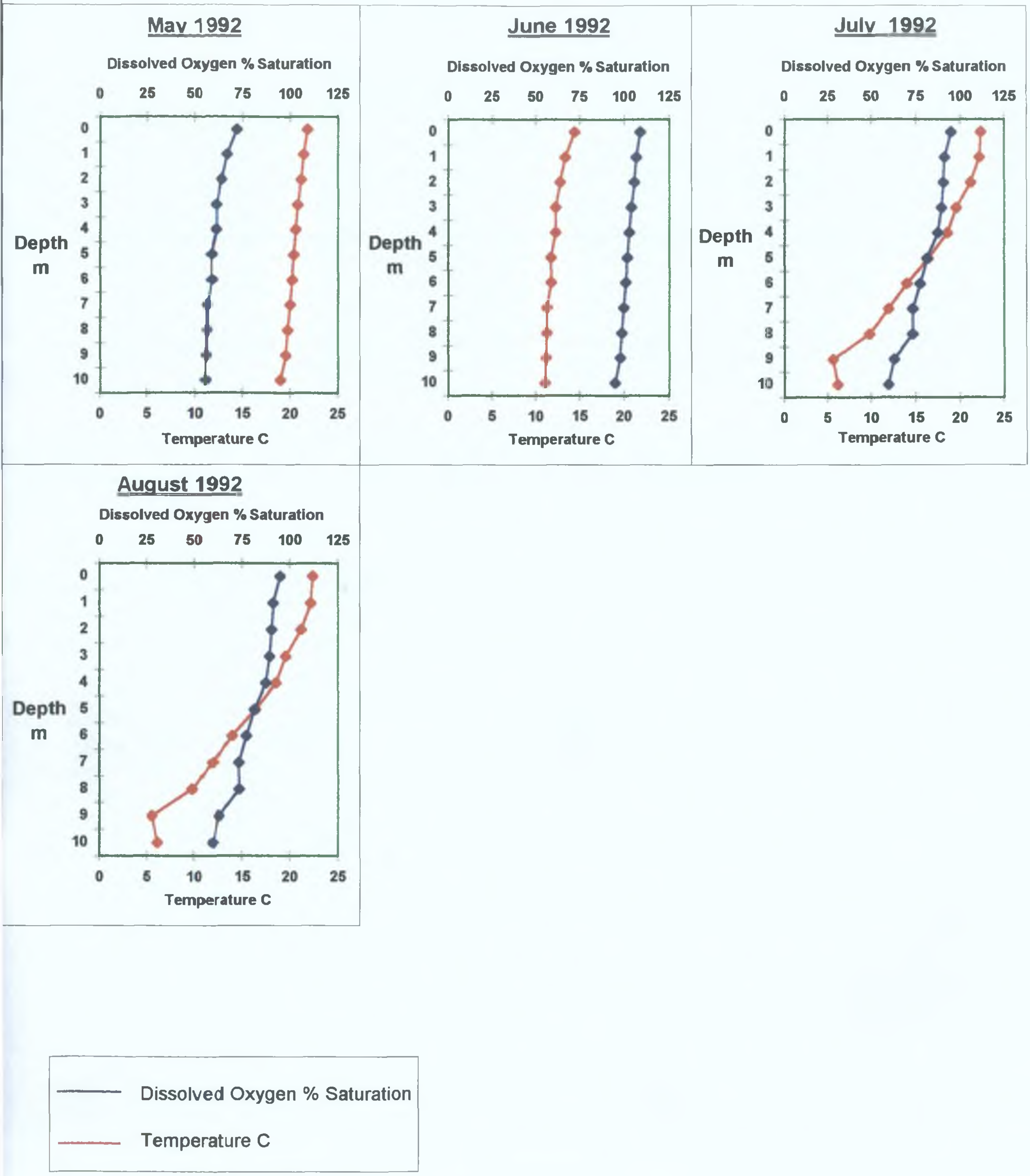


Fig. 8 Vertical profiles of dissolved oxygen and temperature levels in the lake water column (average of all stations)-1992.

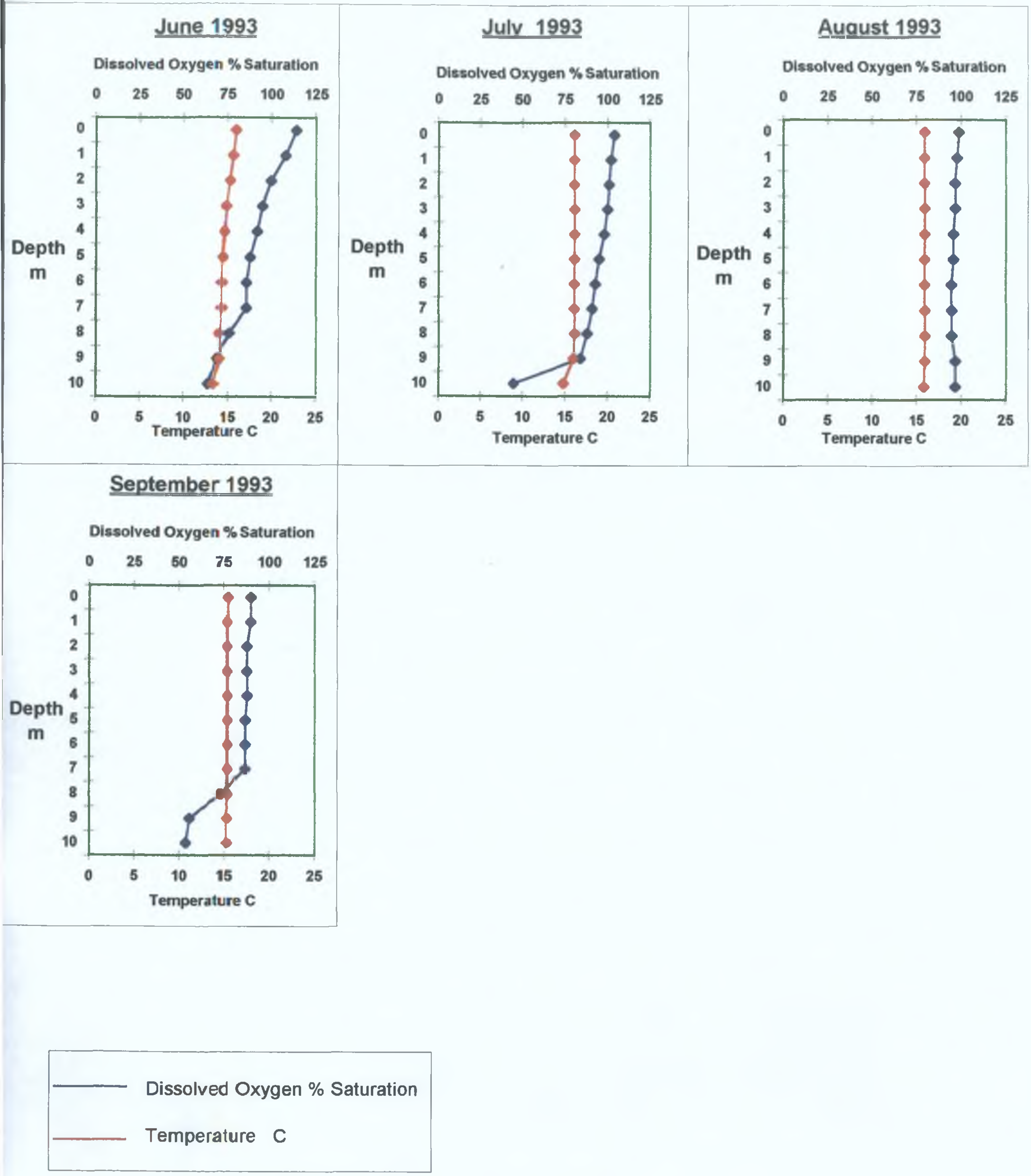


Fig. 9 Vertical profiles of dissolved oxygen and temperature levels in the lake water column (average of all stations)-1993.

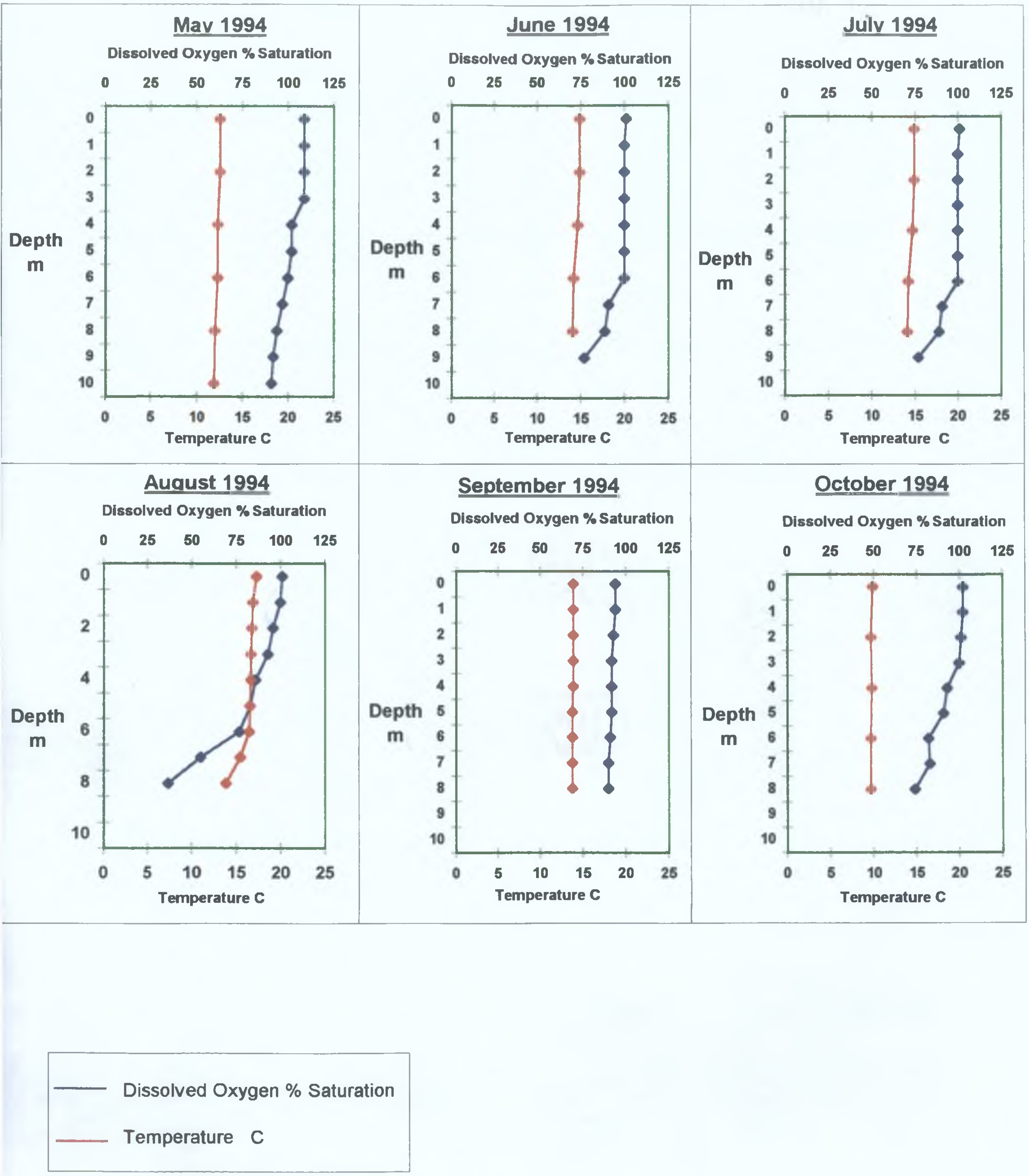


Fig. 10 Vertical profiles of dissolved oxygen and temperature levels in the lake water column (average of all stations)-1994.

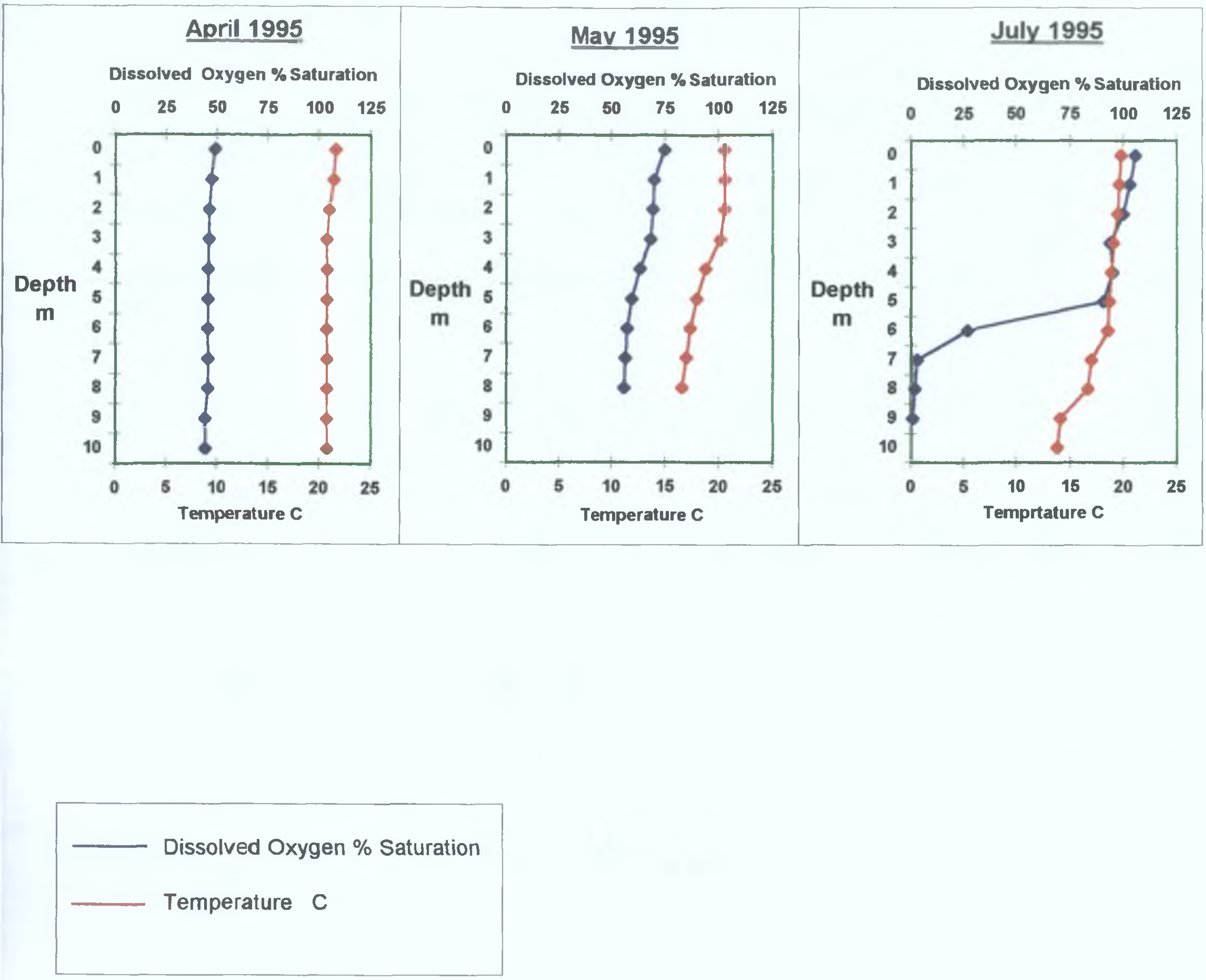


Fig. 11 Vertical profiles of dissolved oxygen and temperature levels in the lake water column (average of all stations)-1995.

5 - Trophic Status and Phosphorus Loading

5.0 Trophic Status

Lakes are usually classified with respect to their capacity to produce organic matter as unproductive and productive (A.F.F. 1975). Production in this sense refers to the development of attached weeds, mosses and sessile algae and free-floating phytoplankton. In many lakes plankton are dominant and are the primary producers. All other production in the lake, the zooplankton, benthic organisms and fish are ultimately dependent on the primary producers. The intensity of primary production in a lake is related to many factors among which the supply of chemical nutrients, especially nitrate and phosphate, assumes great importance. This has led to the classical division of lakes into oligotrophic (poor in nutrients), eutrophic (rich in nutrients) and mesotrophic which is intermediate in character. By definition, oligotrophic lakes are unproductive and eutrophic lakes productive. It is evident from numerous limnological investigations that there is no clear demarcation between the three types and lakes are best considered as a series, ranging from oligotrophic through mesotrophic to eutrophic. Since the overall productivity of lakes depends on the intensity of primary production, the assessment of their trophic status is best inferred from measurements related to this property. This may involve estimates of the abundance of algae by counting their numbers per unit volume of water or by measuring the amount of chlorophyll pigment contained in water samples. In addition, estimation of the amount of nutrients present, particularly phosphate and nitrate, is a more direct way of deciding on trophic status, especially if such work is carried out in early spring before the growing season commences (A.F.F. 1975). The nutrients are then usually present at maximum concentrations. The original distinction between oligotrophic and eutrophic lakes was made in a qualitative manner and referred to a number of biological and physico-chemical features which were readily observable (Table 6).

Table 6. Comparison of the main biological and physiochemical features of oligotrophic (unproductive) and eutrophic (productive) lakes.

Feature	Oligotrophic Lake	Eutrophic Lake
Weed and Algae Growth	Poor - Moderate	Good - Abundant
Dominant types in phytoplankton in Summer	Chlorophyceae (Green Algae) Bacillariophyceae (diatoms)	Myxophyceae (blue-green Algae)
Reed growth in bays	Sparse	May be abundant
Invertebrate Fauna	Sparse, diverse; dominated by insects	Usually abundant and diverse - Dominated by non-insect types
Fish	Dominated by game fish (trout, Salmon, Char); Growth poor.	Usually dominated by coarse fish (roach, bream, rudd, perch) and game may be absent*, good growth
Water Transparency	High in the absence of colour	Low to moderate particularly in summer.
Nutrient Concentrations	Low	Relatively high.
Deoxygenation of lower layers	Never extensive even when the lake is thermally stratified	May be extensive especially when the lake thermally stratified

*Irish lakes seem to be an exception in this respect since game fish thrive in the productive systems. Relatively low surface temperatures and frequent breakdown of the thermocline by wind action in summer are the main features of Irish lakes which permit this situation to occur.

In addition to the three basic categories already referred to, a further two are distinguished in this scheme. Ultra-oligotrophic lakes have extremely low productivity and are usually located in remote mountainous areas, while hyper-eutrophic lakes are subject to an excessive degree of artificial enrichment and produce extremely dense growths of algae.

In recent years attempts have been made to devise a quantitative type of classification (O.E.C.D. 1982) and the resulting distinction of the different trophic categories is shown in Table 7.

Table 7. Suggested values for mean concentrations of chlorophyll *a* [chl] and total phosphorous [p], maximum concentrations of chlorophyll *a* [max chl], and for mean [sec], and minimum,[min sec], transparency to distinguish between lakes of different trophic status (O.E.C.D. 1982).

Trophic Category	[p] mg/m^3	[mean chl] mg/m^3	[max chl] mg/m^3	[mean sec][1] M	[min sec] [1] M
Ultra-oligotrophic	< 4	< 1	< 2.5	> 12	> 6
Oligotrophic	< 10	< 2.5	< 8.0	> 6	> 3
Mesotrophic	10-35	2.5 - 8	8 - 25	6 - 3	3 - 1.5
Eutrophic	35 - 100	8 - 25	25 - 75	3 - 1.5	1.5 - 0.7
Hyper Eutrophic	> 100	> 25	> 75	< 1.5	< 0.7

[1] These values will only apply in lakes which are free of significant water colour.

The more important parameters dealt with in Table 7 are chlorophyll *a* and phosphorus. Chlorophyll *a* is the main pigment of planktonic algae (phytoplankton) and its concentration in samples of water taken from a lake is an indication of the density of algal populations. It is, therefore, the feature of most immediate interest where artificial eutrophication is suspected since most of the adverse effects of such a development relate directly or indirectly to the over abundance of the planktonic algae. However, criteria have yet to be proposed relating chlorophyll concentrations to water uses. The concentrations of phosphorus are also important as this element is usually the limiting factor for algal growth in lakes and a clear relationship between phosphorus and chlorophyll concentrations has been demonstrated in many cases (T. Champ, pers. comm.). In addition to chlorophyll *a* and phosphorus a third parameter, water transparency is one of the traditional methods of assessing lake water quality and, where colour is absent, usually gives a good measure of algal density. This feature is of interest also because high transparency is favoured in lakes used for amenity and recreation and for some types of sports fisheries. It is very easily measured by lowering a circular white plate (Secchi disc) vertically into the water column and noting the depth at which it just becomes invisible.

The scheme of classification set out in Table 7 is artificial in that it implies that rigid boundaries exist between lakes of differing trophic status. In reality, unpolluted lakes exhibit a continuum of types ranging from the ultra-oligotrophic to the eutophic. However, the classification scheme is useful in that it standardises the approach to defining trophic status; this is desirable where the assessments of several investigators are being compared.

In 1975 (AFF, 1975) Lough Gowna was described as follows: "excess production has not been observed but a tendency to such a state has been indicated by the analyses". The analyses showed that chlorophyll *a* levels indicated a relatively large population of algae at several points.

Orthophosphate concentrations were high in the southern section particularly and indicated artificial enrichment. Total phosphate levels were also very high in parts of the southern section. This report also noted that fish kills and dense algal blooms were reported from various points in the lake over the previous years. In another study of Lough Gowna undertaken by An Foras Forbartha (A.F.F. 1977), the water quality measurements, particularly those of phosphorus and chlorophyll *a*, indicated an enhanced eutrophic status in agreement with the findings of the preliminary survey in 1973-74. The composition of the phytoplankton community was consistent with this status, the dense growths of blue-green algae (*Anabaena* sp.) in the northern section being particularly notable. Further indications of the eutrophic status of the two lake basins were the virtually complete removal of nitrate/nitrite from the surface layers in summer and the significant deoxygenation which occurred at the same time below the thermocline at the deeper stations.

In another study of Lough Gowna in 1982/83 carried out again by An Foras Forbatha (AFF, 1984) on behalf of Cavan County Council as part of a water quality management plan, the following observations were made: "Orthophosphate, oxidised nitrogen and ammonia concentrations were low in both sections; however, total phosphorus levels were relatively high. Surface dissolved oxygen levels were fully saturated or slightly supersaturated though marked deoxygenation and chemical enrichment of the hypolimnion was measured in both sections resulting from the establishment of a thermocline. The relatively large algal populations measured are consistent with that of a eutrophic lake. These populations were dominated by the blue green forms, *Anabaena flos-aquae* and *Oscillatoria* sp. in the northern and southern sections, respectively. There was some evidence of occasional organic pollution and nutrient enrichment in most of the inflowing streams to Lough Gowna; however none were consistently polluted. Biological assessments, where these were made, were in concurrence with the physico-chemical data.

The less than satisfactory water quality of the lake outlet (River Erne) noted on occasion, reflects the enriched condition of Lough Gowna".

The water quality monitoring results of Lough Gowna from 1992 to 1995 were used to assess the present trophic status of the lake. Results for mean orthophosphates (although total phosphorus is specified in O.E.C.D. classification), mean and maximum chlorophyll *a* and mean and maximum transparency were used to classify the lake.

Table 8 - Trophic status of Lough Gowna

YEAR	Mean Ortho-phosphates mg/m^3 P	Mean Chlorophyll *a* mg/m^3	Maximum Chlorophyll *a* mg/m^3	Mean Transparency M	Minimum Transparency M
1992 - 1995	25	44	95	0.82	0.5

This shows the lake is eutrophic; the high levels of chlorophyll *a* and the low transparency would indicate the lake is tending towards a hyper-eutrophic condition.

5.1 Comparison between Lough Gowna and an Oligotrophic Lake.

Lough Owel in County Westmeath (950 hectares) is a similar size lake to Lough Gowna. In the early 1970's when it was surveyed by An Foras Forbartha (A.F.F., 1975) the lake was described as unproductive. It has since become eutrophic. At that time it was one of the important midland limestone trout lakes. Water transparency was higher and chlorophyll *a* and orthophosphorus levels were much lower than Lough Gowna. Diatoms were the dominant element in the phytoplankton, the genus *Synedra* being the most important of these. In Lough Gowna the blue-green algae are dominant which is consistent with the trophic status of this lake.

Table 9 - Trophic status of Lough Owel 1973/1974

Year	Mean Orthophosphorus mg/m^3 P	Mean Chlorophyll *a* mg/m^3	Max. Chlorophyll *a* mg/m^3	Mean Transparency (m)	Minimum Transparency (m)
1973/74	7	3.8	4.7	7.5	7

5.2 Phosphate Loading

The control of lake eutrophication by reduction of phosphorus input has been mentioned previously. This formed an important aspect of the O.E.C.D. study referred to above and it is considered useful to give here some details of the main findings and conclusions. The development of criteria for "permissible" and "extensive" inputs of phosphorus was based on a simplified 'input-output' model of the dynamics of phosphorus in lakes as developed originally by Vollenweider (Vollenweider,1976). In this model the main factors regulating phosphorus availability were assumed to be the annual input, expressed as a load per unit surface area, the loss to the sediments due to the sinking of particulate matter and the hydraulic or water retention time of the lake (i.e. the lake volume divided by the annual inflow). In its most simplified form the model showed that the 'steady state' concentration of phosphorus in the lake water body could be predicted from the annual input modified by the hydraulic load (the annual water input per unit surface area) and by the water retention time. Based on past observations it was assumed that a steady state concentration of 10 mg Pm^{-3} would constitute the limit in lakes producing algal biomass of acceptable densities while a doubling of the steady state concentration to 20 mg Pm^{-3} was likely to lead to the excessively productive conditions of eutrophy. Thus, the use of the model to calculate the annual inputs of phosphorus which would lead to these 'steady state' concentrations in lakes of different morphological and hydraulic characteristics gives a scheme of criteria for 'permissible' and 'excessive' phosphorus inputs to such lakes.

"Permissible" and "excessive" annual areal loadings of phosphorus were calculated for Lough Gowna using Vollenweider's equation (Vollenweider, 1976).

$$L[P] = [P]c \,.\, qs\,(1 + \sqrt{Tw})$$

L [P] = annual areal loading of phosphorus mgP m^{-2} yr^{-1}

[P]c = Substitute the values 10 and 20 mg P m^{-3} for [P] c to find permissible and excessive annual areal loadings.

qs = hydraulic load (equivalent to mean depth ($\bar{z}$) divided by hydraulic retention time (Tw)

The average depth of Lough Gowna is 3.66 metres. The hydraulic retention time is calculated by dividing lake volume by total inflow. The lake volume is calculated by the author to be 47.2 X 10^6 m^{-3} by multiplying surface area by average depth. The average annual total inflow is 142 X 10^6 m^{-3}. This gives an hydraulic retention time of 0.33 years.

Substituting these values into the equation above gives 174 mg Pm^{-2} yr^{-1} as a "permissible" annual areal loading of phosphorus and 349 mg Pm^{-2} yr^{-1} as an "excessive" phosphorus loading for Lough Gowna. This is equivalent to 2.24 tonnes P and 4.5 tonnes P, respectively. Thus, inputs of phosphorus to Lough Gowna significantly in excess of 4.5 tonnes per annum are likely to lead to excessive growth of algae.

In assessing the significance of phosphorus inputs to lakes, a further aspect which must be considered is the availability of these inputs to growing algae. In general, phosphorus must be present in the soluble, inorganic 'orthophosphate' form before it can be assimilated by the algae. Most of the phosphate in waste discharges such as sewage or animal manures is present as orthophosphate or as compounds which are readily degraded to this form in receiving waters. Thus, the phosphorus derived from waste inputs is readily taken up by algae, a fact which explains the strongly growth-promoting properties of organic biodegradable wastes. In contrast, a considerable proportion of naturally occurring phosphorus in lake feeder streams is often bound in inorganic or organic compounds of complex composition (e.g. apatites) which are not broken down readily in the lake and, in the case of the particulate fraction, many fall quickly into the sediments. Thus, studies (Peters, 1981; Cowen et al, 1978) have shown that as little as 20 per cent of the phosphorus carried in unpolluted rivers is available to algae. Since the normal practice is to construct phosphorus input budgets on the basis of total phosphorus the impact of such inputs, judged in the framework of the O.E.C.D. scheme of criteria, may be greatly overestimated in cases where the phosphorus is mainly derived from natural sources.

The following equation by Vollenweider (Vollenweider, 1980) relates annual areal loading of phosphorus (L[P], mg P m^{-2} yr^{-1}) to the annual "steady state" concentration of phosphorus ([P] c mg P m^{-3}.

$$L\,[P] = [P]\,c\ (10 + \bar{z}/Tw)$$

The mean orthophosphate concentration in Table 8 of 25 mg Pm^{-3} is used as the "steady state" concentration of phosphorus. Substituting in values for $\bar{z}$ and Tw as before gives an annual orthophosphate loading of 527 mg Pm^{-2} yr^{-1}. This is well in excess of the "excessive" phosphorus loading calculated for Lough Gowna (349 mg Pm^{-2} yr^{-1}) and explains the excessive growth of algae over the last number of years.

An orthophosphate loading for the lake was calculated based on measurements made by the author on 6th March 1996. Twelve feeder rivers and streams were sampled and flow measurements recorded as shown in Table 10. The orthophosphate loading for that day was 0.54 mg Pm^{-2} day^{-1}. If this loading is extrapolated a very crude estimation of the annual orthophosphate loading would be 197 mg Pm^{-2} yr^{-1}. This obviously underestimates the loading rate significantly. Weekly phosphorus analyses and flow rates of feeder streams would be necessary to accurately calculate an annual phosphorus loading for the lake.

It is not to be expected that the degree of compliance between these two methods of estimation should be close because of the relative crudeness of the modelling approach involved and the approximations and assumptions which have been made in carrying out the direct calculations. However, the comparison implies that the loads calculated are of the right order of magnitude.

Table 10. Water quality monitoring of feeder rivers and streams into Lough Gowna

6th March 1996

Sampling Points	Flow M^3/Sec	pH	Temp °C	D.O. % Saturation	B.O.D. mg/l	Nitrate mg/l NO_3-N	Ortho-Phosphate mg/l P	Chloride mg/l	S.S. mg/l	Ammonia mg/l NH^3 -N
1	0.03218	6.8	6.3	97	< 1	1.2	0.0766	17.5	3.00	0.03
2	0.11107	6.7	6.6	95	< 1	1.2	0.0433	16.0	7.50	0.36
3	0.01003	6.6	6.0	88	1.3	0.9	0.1	15.0	1.50	0.44
4	0.09872	7.1	6.1	97	< 1	1.8	0.0866	17.0	0.50	0.16
5	0.01291	6.7	6.7	90	1.3	1.0	0.0366	16.5	0.50	0.42
6	0.05364	7.3	6.2	97	< 1	2.3	0.0866	19.5	2.25	0.19
7	0.01879	7.3	6.5	101	< 1	1.4	0.07	19.5	0.75	0.08
8	4.9	7.4	5.7	98	1.0	0.9	0.0133	19.0	2.25	0.16
9	0.5	7.7	6.7	113	1.2	1.4	0.07	20.0	3.25	0.22
10	0.19362	7.2	7.5	99	< 1	2.6	0.0766	20.5	2.50	0.17
11	4.10391	7.7	5.4	103	1.2	0.8	0.0266	18.0	3.50	0.12
12	0.18405	7.5	7.3	94	< 1	2.2	0.0233	20.0	0.50	0.02
13	0.06754	8.1	7.3	99	< 1	1.0	0.0233	18.5	4.00	0.06
14		7.3	5.1	98	< 1	1.1	0.0266	18.5	3.25	0.15
15	0.00480	7.2	6.9	102	< 1	1.5	0.06	24.0	-----	0.21

1. Culray Bridge (1)
2. Culray Bridge (2)
3. Aughakine
4. Dunbeggan
5. Polladoey
6. Cornadrung
7. Rosduff
* 8. Sallaghan (Erne Outflow)
9. Killsaran (Erne Inflow)
10. Carnagh
* 11. Scrabby Bridge
12. Derrycassin
13. Dring
* 14. Dernaferst Bridge (where northern section enters southern section)
15. Enaghan

Orthophosphate loading for lake on 6th March was 0.54 mg Pm $^{-2}$ day $^{-1}$

*** Not feeder streams.**

6. Control of Farm Wastes

6.0 Pollution Potential of Farm Wastes.

Fertilisers, silage effluent and animal manures are the most important likely sources of nutrient enrichment of natural water arising from agriculture. The source of enrichment of a number of Irish lakes has been attributed, at least in part, to agricultural practices. Farming operations have also been associated with fish-kills. Among the diffuse sources of enrichment (i.e. those which do not enter waters at discrete or identifiable locations), fertilisers, animal manures and silage effluent are the most important for Irish conditions. The potential for pollution by farm wastes has greatly increased with the adoption of intensive livestock rearing methods and with the use of grass silage as animal fodder. These developments have necessitated the storage of large volumes of high strength organic wastes on the farm and their ultimate disposal by spreading on land. In both the storage and disposal phases poor management or negligence can lead to serious pollution of adjacent waterbodies.

Farm wastes, particularly livestock manures and silage run-off, have very high contents of biodegradable organic matter compared to domestic sewage. Volume and concentration of wastes produced by cattle, sheep, pigs and poultry are presented in Table 11.

Table 11. **Volume and concentration of waste produced by cattle, sheep, pigs and poultry**

Waste/day	Cattle	Sheep	Pigs	Poultry
Volume (L)	45	2.5	5.0	0.1
B.O.D. (g)	365	68	100	5
Nitrogen (g)	139	2.5	22.5	1.4
Phosphorus (g)	28	0.5	9.0	0.5

Direct ingress of farm wastes to surface waters is, therefore, liable to lead to serious deoxygenation; this effect is probably the main cause of the fish kills associated with such pollution incidents although conditions may be exacerbated by the presence of toxic compounds. Most of these, if not already in such a form, are readily hydrolysed to the simple salts which are directly available as plant nutrients. Thus, eutrophication and the consequent stimulation of the growth of algae and weeds in surface waters are likely to occur where farm wastes enter such waters in significant quantities, either directly or indirectly.

6.1 Management of Farm Wastes.

Avoidance of pollution by farm wastes generally requires careful management in two areas. Firstly, interception and containment of wastes at the point of generation must be thorough to prevent direct pollution of adjacent waters. Secondly, the ultimate disposal of the wastes, invariably by application to land, must be carried out in a manner which will minimise the carry-over of pollutants to the surface and groundwaters receiving drainage from the disposal area. From a purely technical stand point the first of these control objectives should be the easier to achieve. Careful siting and lay-out of the various farm buildings and other work areas together with the necessary drainage channels to intercept and carry waste to storage and to direct rainfall from roofs away from sources of contamination should be a relatively straightforward matter. Experience (WPAC, 1983) has shown, however, that through poor planning, faulty construction or negligence the area of waste generation on farms is often the source of serious pollution of surface and groundwaters. Silage making operations are, perhaps the most often cited pollution source in this context mainly through failure to intercept the run-off. Another common cause of pollution from the farmyard area is the storage facility either through overflow or leakage.

Apart from the technical appreciation of the control measures needed it is equally important that the farmer appreciates the highly polluting nature of farm wastes and that these may cause problems not just for others but also for himself, e.g. contamination of ground water supplies. This can be achieved only by a thorough programme of education. It seems likely that the greater awareness created by such education will lead to a reduction of the incidence of direct pollution of waters by farm wastes.

The disposal of farm wastes invariably entails spreading on land without any pretreatment other than changes affected in storage (e.g. breakdown of organic matter). When spreading procedures are carefully managed under favourable conditions the disposal of farm wastes on land is a very effective means of water pollution prevention. Best results are likely to be achieved when there is a strong motivation to recover the fertilising values of the wastes to promote crop growth. This is the pattern of traditional agricultural practices in which animal manures are recycled to promote the growth of fodder crops. The nutrient content of farm wastes is substantial and represents a significant resource.

Satisfactory removal of potential water pollutants from farm wastes applied to land is a function of natural factors as well as management practices. Features such as soil type, slope of land, ground temperatures and rainfall are natural factors which may severely limit the amount of and lengths of the periods over which wastes may be applied to land. Thus, the correct management of land spreading will usually require the availability of expert advice from agricultural agencies; in turn these agencies should have the advice of, and be in consultation with, the water pollution control authorities.

6.2 Local Government (Water Pollution) Act, 1977.

This Act now constitutes the main legislation in the water pollution control field.
Section 12 provides safeguards against potential pollution from storage of polluting matters. A local authority may serve on any person having custody of such matters a notice specifying the measures which appear to the local authority to be necessary in order to prevent such matter from entering waters and directing that such measures be taken within a specified period. The person on whom the notice is served may make representations to the local authority in regard to the terms of the notice and the local authority may amend the notice. In default of compliance with a notice the local authority may take such steps as it considers necessary to safeguard against pollution and may recover the cost of such steps as a simple contract debt.

Since 1993 Cavan County Council has issued Section 12 notices to all farmers in the Lough Gowna catchment to ban the spreading of animal wastes during the winter months. One hundred and sixty notices are issued every winter. Longford County Council intend to issue similar notices to approximately 460 farmers in the catchment from next winter to combat pollution by farm wastes.

7. Barley Straw Project

7.0 Introduction

This project was carried out jointly by Cavan and Longford County Councils in 1994. Algal blooms have occurred in Lough Gowna over a number of years, due to excessive nutrient input. The excess nutrients arise from fertiliser runoff and domestic and agricultural waste. The nutrients most involved in this process of eutrophication are nitrate and phosphate. It is likely that high temperatures and low rainfall in recent years have exacerbated the problem by allowing nutrient concentrations to increase, thus providing good conditions for algal growth. The algal blooms have caused significant problems for Longford County Council's water treatment plant at Cornadrung. The blooms have also reduced the aesthetic appeal and amenity potential of this high profile lake. They are also thought to be implicated in large scale fish kills and have altered the whole ecology of the lake (T. Champ, pers. comm.).

7.1 Mode of Action of Straw on Algae.

When the idea of using straw to control algae was first conceived, the hypothesis was formulated that the microbial population on the straw would obtain much of the required nutrients, particularly nitrate and phosphate, from the water. This was tested under laboratory conditions and significant levels of phosphate adsorption, up to 5 µg/g dry weight of straw/hour, were measured. It was further hypothesised that the microflora would subsequently form the basis of a food chain in which invertebrate animals would graze on the microflora and would then become the food source for fish or wildfowl. Therefore, the food chain created diverts nutrients essential for algal growth down a pathway which is unavailable to the algae.

Subsequent research has shown that, although straw-induced nutrient limitation may occur to a limited extent, the primary effect is due to a factor generated during the decomposition of the straw which inhibits the growth of algae. The identity of this factor has not yet been established although various aspects of its production and properties have been identified (Barrett and Newman, 1993).

7.2 Source of the Anti-algal Factor

The anti-algal factor is produced in increasing amounts over a period of about six months from barley straw rotting in water at 20°C. The inhibitory effect is not apparent until the straw has been soaking for about one month; all inhibiting activity is lost if the straw is autoclaved. Both these observations suggest that microbial decomposition is essential to the production of the algal inhibitor. Barley straw is more effective than e.g. wheat or linseed straw. In practice, it may not be necessary to achieve total suppression of algal growth because natural mortality, grazing and other pressures are likely to account for a significant proportion of total production. Algal problems occur when the rate of production exceeds mortality and the effect of straw may be to reduce production rates below mortality rates. Thus it is possible that even lower doses of straw may be sufficient to suppress algal growth to within acceptable limits (Barrett and Newman, 1993).

7.3 Method of Application

Barley straw was placed in the northern section of Lough Gowna in May 1994. The southern section of the lake was untreated and used as a control. Two thousand bales of straw were placed evenly around the lake providing approximately five grams of straw per cubic meter of water. Straw was packed into nylon netting tubes each eight metres long which were then anchored into position. Buoyancy was provided to keep the tubes afloat.

7.4 Results

The lake was monitored over the following months and results are presented below. Dramatic results were not expected during the first year of the trial. Comparisons between the northern and southern sections of the lake from May to November (Tables 12, 13 and 14) shows the treated basin has slightly lower chlorophyll *a* levels. Microscopic examination of the algae in August showed the crop in the treated basin to be distinctly unhealthy -

Microcystis	}	
Coelosphaerium	}	
Anabaena	}	Colonies were small
Aphanizoninon	}	

Oscillatoria...............................Filaments were short/fragmented

Melosira...................................*Melosira* only consisting of 2 or 3 cells.

Phytoplankton also contained a multiplicity of unicellular green algae plus desmids, other diatoms and much detritus.

The southern basin (untreated) contained the same algal species but the crop appeared much healthier -

Melosira..7 - 10 cells

Aphanizomenon.....................................common normal healthy filaments

Oscillatoria sp..common normal healthy filaments

Microcystis...large colonies

Coelosphaerium......................................more numerous

There was a wide range of diatoms, desmids and green algae, and very little detritus. In September, the water in both basins was the same colour but again the algal crop in the treated basin appeared unhealthy while those in the lower untreated area were growing vigorously.

As the barley straw was not placed in the lake until May, the inhibitory effect may have been masked in September following breakdown of stratification and complete mixing of the water body.

When an attempt was made in July 1995 to remove the net 'sausages', on the assumption that all the straw would be rotted away after twelve months, it was in fact discovered that between 25% and 30% of the straw was still undecomposed. If the straw did not decompose at the expected rate then quite obviously the anit-algal factor may not have been released in sufficient quantities to clear up the lake.

Some possible reasons for the straw not decomposing are that the straw may have been packed too tightly, or possibly pesticides used on the barley before harvesting could have interfered with decomposition. The project was abandoned in 1995, but it would be worthwhile repeating in view of the very positive results achieved in other lakes and canals in Ireland.

Fig. 12 Central Fisheries Board monitoring Sites for Barley Straw Project

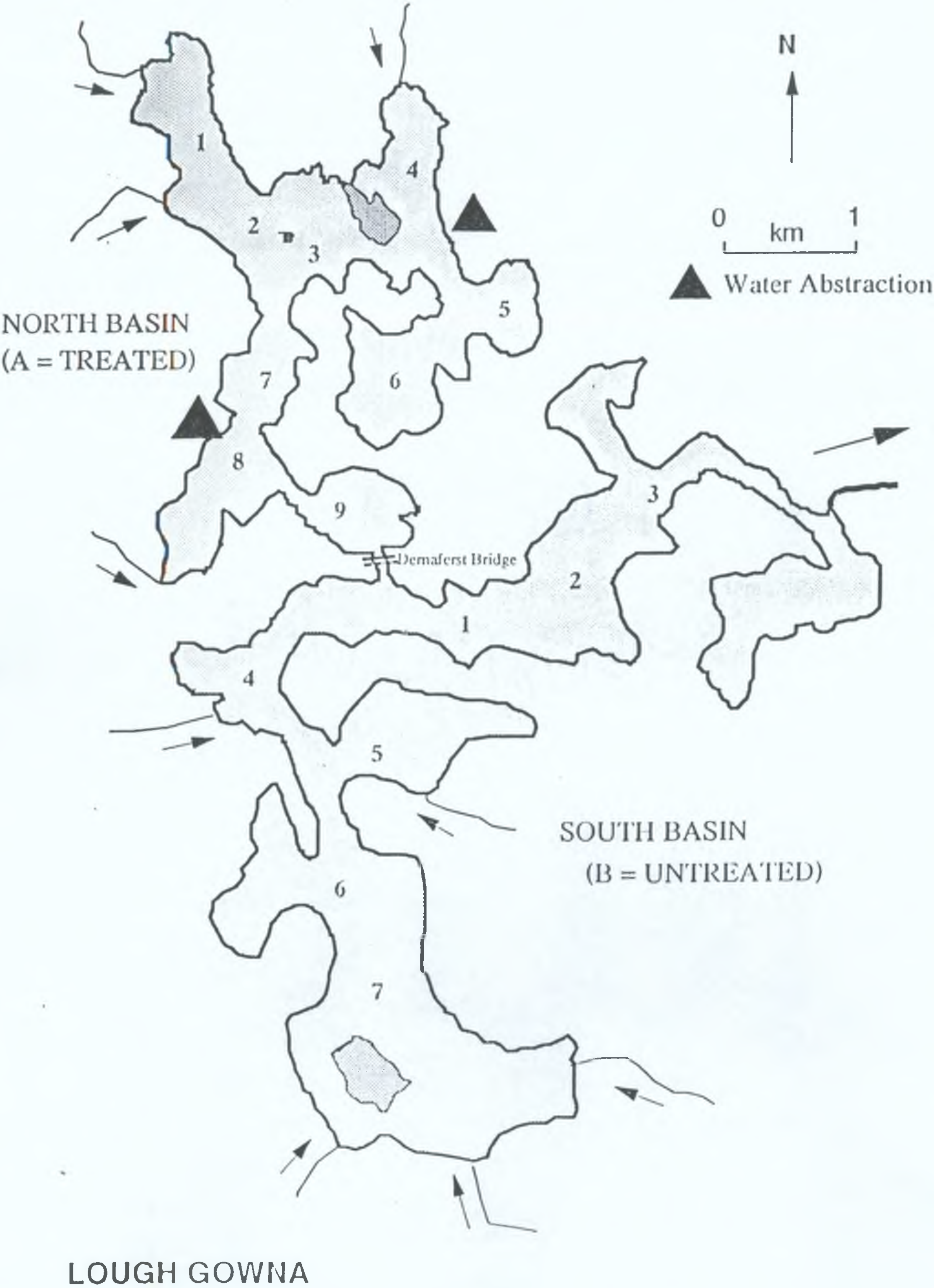


Table 12 - Lough Gowna treated basin (mean monthly values)

	11/5/94	23/5/94	16/6/94	20/7/94	17/8/94	12/9/94	5/10/94	22/11/94
Conductivity µS/cm at 20^0C	118.5	118.8	122.4	125.7	127.6	128	126.5	154.1
Colour °H	65	70	73	70	73	65	76	70
Turbidity N.T.U.	4.5	5	5.4	5.1	8.5	6.9	----	6.55
Total Hardness (mg/l $CaCo_3$)	42.7	44	45	46	47.7	47.3	----	64
Alkalinity (Milli equiv/l)	0.641	0.64	-------	0.713	------	0.736	------	1.047
Total Phosphorus (mg/l P)	0.0558	0.064	0.0768	0.056	0.081	0.082	0.086	0.0905
Orthophosphorus mg/l P	0.003	* 0.002	0.003	0.003	0.015	0.035	0.022	0.0278
T.K.N. mg/l N	0.758	0.716	0.884	0.838	0.55	0.8	0.793	0.892
$NO_2 + NO_3$ mg/l N	0.0347	0.014	N.D	N.D.	0.002	0.008	N.D.	0.142
Chlorophyll µg/l	45.28	41.03	29.07	29.02	42.15	33.7	58.36	54.2
pH	7.72	7.7	7.3	7.4	7.7	7.4	7.72	7.6
No. of Sites	7	9	5	5	5	5	5	4

Note: Persistantly low oxidised nitrogen throughout.
Increasing alkalinity in mid season probably results from lower stream flows.
Mean chlorophyll range 29.07 - 45.3 mg/m^3.
For location of monitoring sites see figure 12.

Central Fisheries Board

Table 13 - Lough Gowna untreated basin (mean monthly values)

	11/5/94	23/5/94	16/6/94	20/7/94	17/8/94	12/9/94	5/10/94	22/11/94
Conductivity µS/cm at 20^{0}C		195	201	204.95	205.45	206.4	205.2	227
Colour °H		70	68	55.0	55.0	65.0	64	60
Turbidity N.T.U.		5.3	4.5	3.85	13.1	10.	-----	6
Total Hardness (mg/l $CaCo_3$)		90	94	95.5	100.5	95	------	110
Alkalinity (Milli equiv/l)		1.7	2.1	1.925	2.2	1.923	2.15	1.95
Total Phosphorus (mg/l P)		0.054	0.054	0.045	0.094	0.085	0.074	0.072
Orthophosphorus mg/l P		0.0016	0.01	0.011	0.019	0.013	0.016	0.013
T.K.N. mg/l N		0.74	0.83	0.725	------	0.835	0.832	0.855
$NO_2 + NO_3$ mg/l N		0.056	0.009	0.063	------	-------	-------	0.14
Chlorophyll µg/l		52.7	13.6	13.588	46.598	29.611	39.459	35.6
pH		8.2	7.8	7.905	7.893	7.890	8.05	7.9
No. of Sites		7	4	4	4	4	4	4

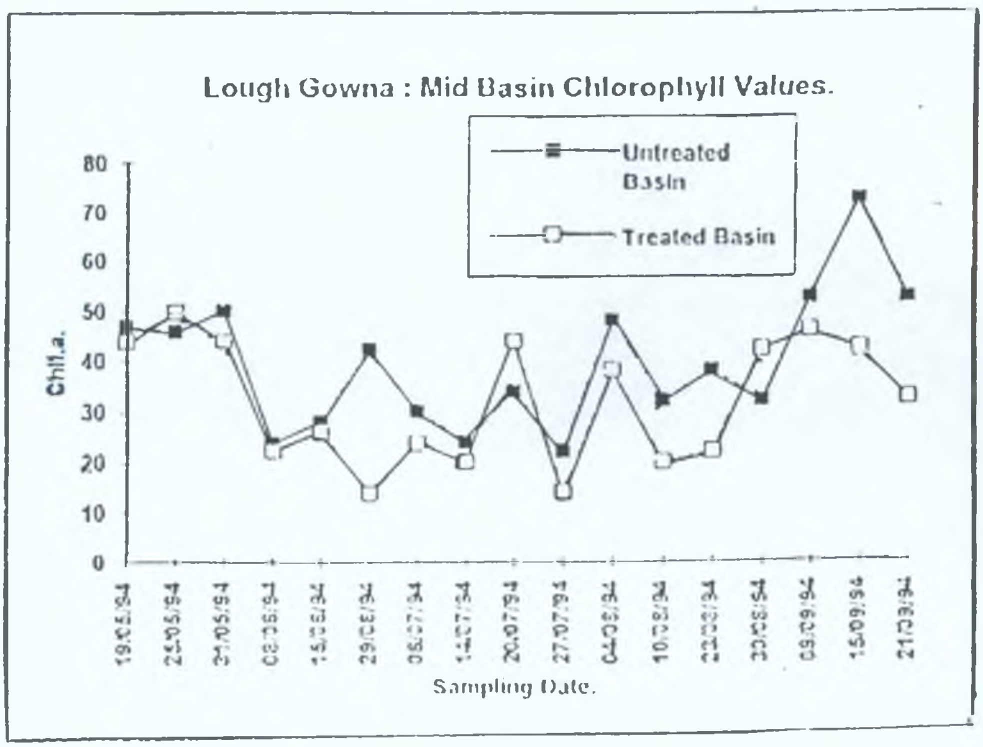
For location of monitoring sites see figure 12

Central Fisheries Board

Table 14 Cavan County Council monitoring data for Barley Straw Project

Cavan County Council.
Lough Gowna : 1994 Monitoring Data.

	Station 1: (South)			Station 4 : (North)		
Date.	Chll.a (mg/m3)	Comp.OP (mg/l P)	Comp. Amn (mg/l N)	Chll.a (mg/m3)	Comp.OP. (mg/l P)	Comp.Amn (mg/l N)
19/05/94	47	0.021.		44	0.019	
25/05/94	46	0.021	0.029	50	0.019	0.033
31/05/94	50			44	0.018	0.031
08/06/94	24	0.021	0.047	22	0.025	0.052
15/06/94	28	0.021	0.017	26	0.021	0.023
29/06/94	42	0.02	0.025	14	0.024	0.029
06/07/94	30	0.015	0.036	24	0.024	0.075
14/07/94	24	0.016	0.123	20	0.023	0.104
20/07/94	34	0.019	0.095	44	0.032	0.082
27/07/94	22	0.035	0.161	14	0.036	0.119
04/08/94	48	0.027	0.075	38	0.034	0.138
10/08/94	32	0.032	0.052	20	0.053	0.127
23/08/94	38	0.033	0.051	22	0.047	0.076
30/08/94	32	0.038	0.038	42	0.038	0.046
09/09/94	52.5	0.034	0.033	46	0.035	0.042
15/09/94	72.5	0.028	0.039	42	0.039	0.058
21/09/94	52.4	0.034	0.024	32.2	0.046	0.045



8. Conclusion

1. There are no industrial or sewage discharges directly to watercourses in the catchment except the effluent from Kilnaleck Sewerage Scheme, which is relatively small in terms of volume.

2. The most probable source of pollution of Lough Gowna is therefore of agricultural origin. This would include run-off from agricultural land of artificial fertilisers and animal wastes, and point discharges of animal wastes and silage effluent from farmyards.

3. Controlling the growth of algae with barley straw is only a short term solution. The sources of nutrient enrichment in the lake need to be identified and reduced or eliminated.

4. The large dependence on livestock husbandry (as shown by the relatively high stocking density of cattle and the number of piggeries (10) in the catchment) will give rise to a considerable volume of wastes to be disposed of on land. There is a need for more control and monitoring of the disposal operations. The issuing of notices under Section 12 of the Local Government (Water Pollution) Act, 1977 to combat landspreading of wastes during winter will go someway towards limiting the pollution potential of such activities.

Perhaps a more long-term solution would be to limit the number of pigs in the catchment. The optimum number could be based on topography, type of soil in the area, rainfall and on the phosphorus budget for the catchment. This could be achieved through the Local Government (Planning and Development) Acts 1963 - 1983.

5. There is a lack of hydrometric data for the catchment. There is need for an automatic recorder in the northern section of Lough Gowna and on the River Erne flowing into the lake.

6. There should be co-operation between Longford and Cavan County Councils in monitoring water quality in the area. Perhaps Cavan County Council could concentrate on monitoring the lake and Longford County Council could monitor all feeder rivers and streams. This approach would make better use of available resources and avoid overlapping the work.

7. A detailed survey to find annual phosphorus loading to the lake should be commissioned. This is needed in light of the high algae levels experienced in recent years.

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APPENDICES

Appendix A

Table A1 Cavan County Council water quality monitoring data

Station 1

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	2.0	127	9.1	20	4.3	0.042	0.17	63.7
1993	1.5	157	9.03	18.7	6.3	0.04	0.083	56.4
1994	1.0	128	8.45	20.3	----	0.041	0.057	72.5
1995	0.65	122	8.51	19.3	3.7	0.034	0.051	76.6

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.6	93	8.0	10.8	1.6	0.011	0.037	8.6
1993	0.6	92	8.05	13.3	1.6	0.014	0.016	6.6
1994	0.55	86	7.5	7.5	-----	0.013	0.014	22
1995	0.5	96	7.34	10.5	3.2	0.033	0.028	42.3

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.1	107	8.6	16.9	3.0	0.021	0.054	29.1
1993	0.9	105	8.4	15.9	3.6	0.028	0.044	38.3
1994	0.8	96	7.82	15.3	-----	0.026	0.032	39.9
1995	0.56	106	7.93	15.7	3.4	0.033	0.042	59.7

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.54	12.7	0.46	2.7	1.0	0.01	0.046	17.7
1993	0.29	22	0.33	1.5	1.3	0.009	0.21	18.9
1994	0.15	9	0.44	3.2	-----	0.009	0.011	12.2
1995	0.07	10	0.42	4.3	0.4	0.001	0.009	15.4

Table A2 Cavan County Council water quality monitoring data

Station 2

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.75	150	9.21	21.7	12.0	0.042	0.170	63.7
1993	1.0	136	8.75	19.3	6.5	0.04	0.098	54.5
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	129	8.07	21.9	4.8	-----	0.035	74.6

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.60	98	8.26	15.8	1.9	0.011	0.037	8.6
1993	0.60	94	7.85	13.8	1.7	0.019	0.015	9.6
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	108	7.63	19.4	3.9	-----	0.032	56.4

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.86	116	8.66	18.4	4.1	0.028	0.07	32.7
1993	0.74	104	8.31	15.9	3.7	0.028	0.048	36.7
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	118	7.85	20.7	4.35	-----	0.033	65.5

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.42	17.4	0.38	2.1	3.3	0.011	0.035	24.9
1993	0.15	13.8	0.3	1.6	1.5	0.008	0.03	13.2
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	15	0.31	1.8	0.6	-----	0.002	12.9

Table A3 Cavan County Council water quality monitoring data

Station 3

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.75	150	9.21	21.7	12	0.042	0.17	63.7
1993	1.00	136	8.75	19.3	6.5	0.04	0.098	54.5
1994	-----	-----	-----	-----	-----	------	-----	-----
1995	-----	129	8.07	21.9	4.8	-----	0.035	74.6

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.60	98	8.26	15.8	1.9	0.011	0.037	8.6
1993	0.60	94	7.85	13.8	1.7	0.019	0.015	9.6
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	108	7.63	19.4	3.9	-----	0.032	56.4

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.86	116	8.66	18.4	4.1	0.028	0.07	32.7
1993	0.74	104	8.31	15.9	3.7	0.028	0.048	36.7
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	118	7.85	20.65	4.35	-----	0.033	65.5

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.42	17.4	0.38	2.1	3.3	0.011	0.035	24.9
1993	0.15	13.8	0.3	1.6	1.5	0.008	0.03	13.2
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	15	0.31	1.8	0.6	-----	0.002	12.9

Table A4 Cavan County Council water quality monitoring data

Station 4

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.8	137	9.3	22	4.1	0.04	0.085	46.8
1993	1.3	161	9.4	19.8	7.6	0.04	0.175	81.0
1994	1.0	133	8.9	19.8	-----	0.053	0.099	56.4
1995	0.75	109	8.3	20.8	3.0	0.034	0.061	84.7

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.9	98	7.9	16.7	1.3	0.009	0.031	4.0
1993	0.5	92	7.5	13.6	2.0	0.015	0.007	9.1
1994	0.5	83	6.9	7.7	-----	0.013	0.012	14.0
1995	0.6	91	7.1	9.5	2.1	0.027	0.008	44.3

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.2	114	8.6	18.6	2.6	0.019	0.053	20.5
1993	0.8	106	8.2	16	3.8	0.028	0.054	53.3
1994	0.82	99	7.5	14.7	-----	0.032	0.042	35.3
1995	0.65	101	7.7	14.8	2.5	0.029	0.035	60

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.36	15.1	0.6	1.92	1.0	0.24	0.025	19.1
1993	0.2	22	0.6	1.7	1.6	0.07	0.2	24.7
1994	0.11	12	0.5	3	-----	0.014	0.021	13.1
1995	0.06	7	0.48	5.1	0.6	0.003	0.019	14.5

Table A5 Cavan County Council water quality monitoring data

Station 5

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992								
1993								
1994								
1995	0.5	107	7.64	20.8	4.0	-----	0.078	74.6

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992								
1993								
1994								
1995	0.5	101	7.41	19.1	3.9	-----	0.032	68.5

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992								
1993								
1994								
1995	0.5	104	7.5	20.0	3.9	-----	0.055	71.5

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992								
1993								
1994								
1995	0	4	0.16	1.2	0.1	-----	0.033	4.3

Table A6 Cavan County Council water quality monitoring data

Station 6

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	2.0	146	9.14	21.8	4.6	0.041	0.095	54.0
1993	1.5	157	8.73	19.2	3.1	0.043	0.101	54.5
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	0.6	103	7.38	19.2	3.2	-----	0.032	68.5

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.6	98	8.26	15.8	2.5	0.005	0.03	2.3
1993	0.6	94	8.0	13.4	1.3	0.002	0.031	6.6
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	0.6	103	7.38	19.2	3.2	-----	0.032	68.5

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.0	119	8.78	18.6	3.4	0.017	0.054	32.6
1993	1.0	108	8.32	16.0	2.6	0.022	0.074	31.8
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	0.6	103	7.38	19.2	3.2	-----	0.032	68.5

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.52	17.3	0.36	2.1	0.8	0.013	0.026	22.5
1993	0.4	27	0.29	2.1	0.8	0.015	0.026	20.7
1994	-----	-----	-----	-----	-----	-----	-----	-----
1995	-----	-----	-----	-----	-----	-----	-----	-----

Table A7 Cavan County Council water quality monitoring data

Station 7

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.5	129	9.3	22.3	5.0	0.027	0.080	38.7
1993	1.2	134	9.44	19.2	5.6	0.049	0.212	94.7
1994								
1995								

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.8	101	7.92	16.6	1.4	0.005	0.025	1.6
1993	0.6	88	7.69	13.7	1.4	0.015	0.026	5.5
1994								
1995								

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.1	113	8.67	19.2	2.6	0.014	0.049	19.6
1993	0.8	100	8.17	16.1	3.6	0.031	0.074	46.5
1994								
1995								

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.27	10.4	0.55	2.7	1.3	0.008	0.022	17.1
1993	0.2	15	0.57	1.6	1.1	0.011	0.06	24.9
1994								
1995								

Table A8 Cavan County Council water quality monitoring data

Station 8

MAXIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.4	141	9.3	20.9	3.9	0.029	0.080	45.1
1993	1.4	150	9.6	19.1	6.7	0.061	0.218	67.0
1994								
1995	0.7	108	8.18	9.5	-----	0.034	0.041	88.7

MINIMUM								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.90	105	7.8	18.2	1.8	0.01	0.02	7.3
1993	0.60	89	7.3	13.9	1.9	0.013	0.028	5.0
1994								
1995	0.7	108	8.18	9.5	-----	0.034	0.041	88.7

MEAN								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	1.1	124	8.7	19.8	2.7	0.016	0.058	26.4
1993	0.77	101	8.0	15.9	3.5	0.035	0.089	44.3
1994								
1995	0.7	108	8.18	9.5	-----	0.034	0.041	88.7

STANDARD DEVIATION								
	Secchi Disc (m)	D.O. % Sat.	pH	Temp °C	B.O.D. mg/l O_2	Ortho.P mg/l P	Ammonia mg/l N	Chlorophyll *a* mg/m^3
1992	0.2	12.8	0.7	1.4	0.9	0.007	0.025	16.1
1993	0.26	20	0.7	1.5	1.5	0.01	0.08	21.5
1994								
1995								

Appendix B

Table B1 - Environmental Protection Agency water quality monitoring data

Kilsaran Bridge

MAXIMUM								
Year	**Temp Deg. C**	**D.O, % Sat.**	**B.O.D. mg/l**	**Cond. uS/cm**	**pH**	**Orthophos-phorus mg/l P**	**Ammonia mg/l N**	**Nitrate mg/l N**
1992	19	105	5.9	330	7.8	0.160	0.230	2.56
1993	16	144	3.6	279	7.9	0.160	0.190	1.67
1994	18	102	4.1	258	7.7	0.160	0.160	1.63

MINIMUM								
Year	**Temp Deg. C**	**D.O, % Sat.**	**B.O.D. mg/l**	**Cond. uS/cm**	**pH**	**Orthophos-phorus mg/l P**	**Ammonia mg/l N**	**Nitrate mg/l N**
1992	5.0	62	1.0	175	6.8	0.00	0.00	0.010
1993	4.0	72	0.7	184	7.1	0.03	0.01	0.17
1994	3.0	71	1.4	163	7.3	0.03	0.01	0.24

MEAN								
Year	**Temp Deg. C**	**D.O, % Sat.**	**B.O.D. mg/l**	**Cond. uS/cm**	**pH**	**Orthophos-phorus mg/l P**	**Ammonia mg/l N**	**Nitrate mg/l N**
1992	12.3	82.4	2.1	250	7.314	0.081	0.070	0.812
1993	10.3	88	1.9	228	7.5	0.078	0.050	0.822
1994	9.9	86	2.2	207	7.5	0.093	0.060	0.756

STANDARD DEVIATION								
Year	**Temp Deg. C**	**D.O, % Sat.**	**B.O.D. mg/l**	**Cond. uS/cm**	**pH**	**Orthophos-phorus mg/l P**	**Ammonia mg/l N**	**Nitrate mg/l N**
1992	4.3	12.5	1.04	46.3	0.2	0.036	0.055	0.687
1993	4.2	14	0.61	24	0.2	0.027	0.040	0.422
1994	4.6	7.3	0.71	23	0.124	0.092	0.052	0.397

Table B2 - Environmental Protection Agency water quality monitoring data

Sallaghan Bridge

MAXIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	20	117	6.5	245	8.0	0.08	0.19	1.67
1993	17	127	5.6	221	8.0	0.11	0.1	1.59
1994	19	118	8.1	212	8.3	0.07	0.23	1.04

MINIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	5.0	70	1.1	180	7.0	0.00	0.00	0.01
1993	4.0	76	1.1	168	7.4	0.01	0.01	0.01
1994	3.0	76	1.7	161	7.4	0.01	0.01	0.01

MEAN								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	12.66	89	2.8	213	7.5	0.030	0.044	0.52
1993	10.6	90	3.2	201	7.7	0.037	0.028	0.48
1994	10.5	91	3.8	186	7.7	0.026	0.080	0.39

STANDARD DEVIATION								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	4.9	11	1.39	17	0.26	0.024	0.042	0.536
1993	4.8	11	1.1	12	0.21	0.018	0.027	0.44
1994	5.0	9	1.8	10	0.22	0.019	0.05	0.38

Table B3 - Environmental Protection Agency water quality monitoring data

Scrabby Bridge

MAXIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	19	118	6.6	220	8.7	0.07	0.08	0.89
1993	17	135	4.1	204	8.4	0.08	0.07	1.07
1994	18	102	6.0	197	8.8	0.04	0.12	0.78

MINIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	5.0	73	1.1	190	7.2	0.000	0.000	0.010
1993	4.0	77	1.1	159	7.5	0.010	0.000	0.010
1994	3.0	76	1.4	166	7.2	0.010	0.010	0.010

MEAN								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	10.83	92.1	2.9	206	7.7	0.027	0.035	0.28
1993	10.83	92	3.0	212	7.8	0.027	0.018	0.34
1994	10.58	92	3.1	180	7.9	0.015	0.02	0.19

STANDARD DEVIATION								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	4.76	12.18	1.63	7.18	0.4	0.018	0.026	0.29
1993	4.76	12.21	1.07	104.86	0.3	0.018	0.015	0.32
1994	4.92	7	1.3	6.85	0.3	0.008	0.03	0.23

Table B4 - Environmental Protection Agency water quality monitoring data

Dernaferst Bridge

MAXIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	20	123	4.6	170	8.8	0.06	0.08	1.03
1993	18.0	146	9.1	156	9.7	0.05	0.10	0.96
1994	19.0	104	4.3	195	8.8	0.05	0.13	0.84

MINIMUM								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	5.0	87	1.3	140	7.4	0.00	0.00	0.01
1993	5.0	65	1.1	137	7.4	0.01	0.01	0.01
1994	4.0	66	1.6	117	7.3	0.01	0.01	0.01

MEAN								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	13.1	101	2.6	150	7.8	0.018	0.029	0.313
1993	11.1	102	3.5	144	8.1	0.03	0.028	0.333
1994	10.9	93	3.0	130	8.0	0.02	0.02	0.18

STANDARD DEVIATION								
Year	Temp Deg. C	D.O, % Sat.	B.O.D. mg/l	Cond. uS/cm	pH	Orthophos-phorus mg/l P	Ammonia mg/l N	Nitrate mg/l N
1992	5.0	9	1.1	7	0.5	0.013	0.023	0.363
1993	4.9	17	2.0	5	0.6	0.01	0.026	0.290
1994	5.0	9	1.0	15	0.6	0.01	0.03	0.234

Appendix C

Table C1 Northern Regional Fisheries Board water quality monitoring data

Sallaghan Bridge

MAXIMUM				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.051	0.108	1.222	1.202
1986	0.063	0.098	1.198	1.347
1987	0.049	0.101	1.183	0.825
1988	0.062	0.108	0.933	1.217
1989	0.045	0.214	2.091	1.439
1990	0.068	0.127	1.569	2.340
1991	0.065	0.132	1.537	3.627
1992	0.110	0.195	1.719	1.819
1993	0.085	0.123	1.233	1.674
1994	0.157	0.310	1.825	1.379
1995	0.060	0.292	3.179	1.844

MINIMUM				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.037	0.096	1.096	0.373
1986	0.000	0.049	0.660	0.000
1987	0.000	0.045	0.554	0.000
1988	0.001	0.041	0.513	0.080
1989	0.002	0.057	0.654	0.000
1990	0.001	0.046	0.648	0.000
1991	0.001	0.050	0.718	0.003
1992	0.002	0.054	0.848	0.011
1993	0.016	0.056	0.771	0.000
1994	0.013	0.050	0.784	0.000
1995	0.019	0.062	0.689	0.000

Table C1 (Contd.) Northern Regional Fisheries Board water quality monitoring data

Sallaghan Bridge

MEAN				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.043	0.100	1.168	0.778
1986	0.022	0.070	0.933	0.452
1987	0.020	0.066	0.879	0.343
1988	0.032	0.069	0.719	0.507
1989	0.024	0.096	1.014	0.452
1990	0.018	0.077	0.955	0.900
1991	0.024	0.078	1.013	0.917
1992	0.030	0.092	1.072	0.857
1993	0.034	0.085	1.033	0.537
1994	0.050	0.115	1.174	0.601
1995	0.044	0.114	1.155	0.519

STANDARD DEVIATION				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.007	0.007	0.065	0.415
1986	0.019	0.016	0.168	0.497
1987	0.017	0.018	0.208	0.324
1988	0.018	0.018	0.144	0.312
1989	0.014	0.048	0.438	0.499
1990	0.019	0.028	0.268	0.925
1991	0.017	0.026	0.276	1.063
1992	0.035	0.044	0.273	0.650
1993	0.020	0.024	0.174	0.524
1994	0.049	0.078	0.351	0.462
1995	0.014	0.124	0.648	0.645

Table C2 Northern Regional Fisheries Board water quality monitoring data

Dernaferst Bridge

MAXIMUM				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.025	0.057	0.888	0.448
1986	0.024	0.086	1.015	0.664
1987	0.022	0.055	0.919	0.506
1988	0.024	0.059	0.772	0.558
1989	0.041	0.098	1.042	0.691
1990	0.019	0.072	1.285	1.477
1991	0.030	0.097	1.201	1.306
1992	0.016	0.220	1.652	1.018
1993	0.030	0.114	1.440	0.715
1994	0.043	0.138	1.092	0.485
1995	0.043	0.634	5.599	0.856

MINIMUM				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.004	0.042	0.801	0.182
1986	0.000	0.020	0.674	0.000
1987	0.000	0.023	0.345	0.000
1988	0.000	0.030	0.364	0.000
1989	0.001	0.028	0.543	0.000
1990	0.001	0.032	0.493	0.010
1991	0.001	0.031	0.678	0.000
1992	0.001	0.032	0.691	0.000
1993	0.007	0.042	0.656	0.000
1994	0.009	0.042	0.738	0.000
1995	0.003	0.054	0.694	0.000

Table C2 (Contd.) Northern Regional Fisheries Board water quality monitoring data

Dernaferst Bridge

MEAN				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.018	0.050	0.832	0.350
1986	0.004	0.045	0.803	0.194
1987	0.009	0.043	0.646	0.180
1988	0.009	0.045	0.556	0.262
1989	0.012	0.052	0.755	0.240
1990	0.005	0.051	0.871	0.522
1991	0.010	0.056	0.868	0.536
1992	0.009	0.068	0.972	0.472
1993	0.017	0.062	0.993	0.290
1994	0.022	0.078	0.922	0.221
1995	0.025	0.128	1.25	0.238

STANDARD DEVIATION				
	Orthophosphorus mg/l P	Total Phosphorus mg/l P	T.K.N mg/l N	$NO_2 + NO_3$ mg/l N
1985	0.012	0.008	0.049	0.146
1986	0.007	0.016	0.124	0.245
1987	0.008	0.009	0.162	0.191
1988	0.008	0.010	0.145	0.183
1989	0.014	0.019	0.150	0.240
1990	0.005	0.014	0.259	0.566
1991	0.010	0.019	0.161	0.482
1992	0.005	0.052	0.335	0.397
1993	0.007	0.021	0.257	0.283
1994	0.011	0.029	0.125	0.202
1995	0.011	0.161	1.361	0.314

Appendix D

Table D1 Longford County Council water quality monitoring data - October 1988

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge										
2. Cornadrung	7.47	9.4	5.3	1.5	-	0.038	0.09	25.5	3.5	17.0
3. Dunbeggan	7.36	8.7	3.8	1.8	-	0.02	0.16	14.1	1.0	17.0
4. Dring	7.70	9.1	5.6	0.9	-	0.01	0.35	22.4	3.5	17.5
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.35	8.0	6.0	0.6	-	0.04	N.D.	1.25	2.5	17.0
8. Dring										

Table D2 Longford County Council water quality monitoring data - August 1989

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	7.4	16.0	-	4.0	0.175	<0.05	<0.1	64	10	27
2. Cornadrung	7.5	16.0	-	3.0	0.155	<0.05	0.30	47	145	22.5
3. Dunbeggan	7.7	15.0	-	2.1	0.075	<0.05	0.20	-	3.5	25.5
4. Dring	8.1	15.0	-	4.3	0.075	<0.05	0.15	50	6.5	21.0
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.7	13.5	-	2.2	> 1.5	0.10	0.35	10	9.5	32.5
8. Dring										

Table D3 Longford County Council water quality monitoring data - April 1990

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	7.0	8.0		2.0	1.6	< 0.05	0.35	10	9.0	
2. Cornadrung	7.1	8.0		1.1	1.7	< 0.05	0.2	0	1.0	
3. Dunbeggan	7.5	6.0		2.4	1.0	< 0.05	0.2			
4. Dring	8.0	7.0		3.7	1.4	< 0.05	0.2	10	1.5	
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.3	5.0		1.1	0.8	< 0.05	0.2	0	1.0	
8. Dring										

Table D4 Longford County Council water quality monitoring data - May 1991

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	7.7	17.0	101	1.7		< 0.05	0.3		1.0	20.0
2. Cornadrung	8.0	17.0	97	2.1		< 0.05	0.15		1.0	20.0
3. Dunbeggan										
4. Dring	8.2	16.0	103	1.9		< 0.05	0.3		1.0	20.0
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.7	11.0	95	1.9		< 0.05	0.2		1.0	20.0
8. Dring										

Table D5 Longford County Council water quality monitoring data - August 1992

Sampling Point	pH	Temp. ^{0}C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3-N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3-N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	8.8	16.6	103	8.2	0.2	0.01	0.13	66.72	7.75	20.0
2. Cornadrung	7.5			7.9	0.1	0.01	0.12	54.21	10.25	23.5
3. Dunbeggan										
4. Dring	7.5			5.3	0.1	0.02	0.12	41.7	16.0	27.5
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.6			1.7	0.5	0.31	0.38	4.17	2.5	18.5
8. Dring										

Table D6 Longford County Council water quality monitoring data - July 1993

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	7.52	16.7	94	6.0	0.20	0.06	0.20	50		
2. Cornadrung	7.67	16.7	87	5.5	0.20	0.15	1.98	30		
3. Dunbeggan										
4. Dring	7.53	16.8	89	4.9	0.19	0.19	0.18	45		
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.70	16.6	96	6.2	0.22	0.20	0.15	5		
8. Dring										

Table D7 Longford County Council water quality monitoring data - July 1994

Sampling Point	pH	Temp. ^0C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	7.1	17.0	82	2.8	0.3	N.D.	0.21	26	9.4	19.5
2. Cornadrung	7.2	17.9	95	2.3	0.2	0.01	0.22	33	8.8	18.5
3. Dunbeggan										
4. Dring	7.5	17.1	92	> 8	0.3	0.17	0.25	25	6.0	18.5
Feeder Streams										
5. Rosduff										
6. Cornadrung										
7. Dunbeggan	7.2	13.6	94	4.1	1.6	0.28	0.40	15	7.0	22.0
8. Dring										

Table D8 Longford County Council water quality monitoring data - November 1995

Sampling Point	pH	Temp. ^{0}C	Dissolved Oxygen mg/l	B.O.D. mg/l	Nitrates NO_3 -N mg/l	Orthophosphate PO_4 - mg/l	Ammonia NH_3 -N mg/l	Chlorophyll *a* mg/m^3	Suspended Solids mg/l	Chlorides mg/l Cl.
1. Dernaferst Bridge	6.9	7.5	80	4	0.7	0.12	0.11		6	20.0
2. Cornadrung	7.0	7.7	81	2	0.8	0.15	0.14		10	21.0
3. Dunbeggan										
4. Dring	7.1	7.3	85	2	0.6	0.25	0.13		4	20.0
Feeder Streams										
5. Rosduff	6.9	7.9	94	1	1.7	0.03	0.11		2	20.0
6. Cornadrung	6.6	7.9	93	2	2.4	0.05	0.31		3	20.0
7. Dunbeggan	6.8	7.7	96	3	1.5	0.01	0.27		5	20.0
8. Dring	7.4	8.2	90	1.5	0.9	0.03	0.05		4	21.0

Appendix E

Table E1 Dissolved oxygen and temperature levels in the lake water column (average of all stations) - 1992

	MAY		JUNE		JULY		AUGUST	
Depth (m)	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C
0	109	14.4	112	19	118	19.4	99	16.4
1	107	13.4	111	18.3	117	18.3	97	16.4
2	106	12.8	106	18.1	110	17.9	97	16.3
3	104	12.3	98	17.9	102	17.7	96	16.3
4	103	12.3	93	17.5	100	17.6	96	16.2
5	102	11.8	82	16.3	90	17.5	96	16.2
6	101	11.8	70	15.5	55	16.8	94	16.2
7	100	11.3	60	14.7	54	16.5	90	16.1
8	99	11.3	49	14.7	44	16.9	---	---
9	98	11.2	28	12.6	24	15.2	---	---
10	95	11.1	31	12	2	---	---	---

Table E2 Dissolved oxygen and temperature levels in the lake water column (average of all stations) - 1993

	JUNE		JULY		AUGUST		SEPTEMBER	
Depth (m)	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C
0	114	16	104	16.1	99	16	90	15.5
1	108	15.7	102	16.1	98	16	90	15.4
2	100	15.3	101	16.1	97	16	88	15.4
3	95	14.9	100	16.1	97	16	88	15.4
4	92	14.7	98	16.1	96	16	88	15.4
5	88	14.5	95	16.1	96	16	87	15.4
6	86	14.4	93	16.1	95	16	87	15.4
7	86	14.4	91	16.1	95	16	87	15.4
8	76	14.1	88	16.1	95	16	73	15.4
9	69	14.1	84	16	97	16	56	15.3
10	64	13.4	45	14.8	97	15.9	54	15.3

Table E3 Dissolved oxygen and temperature levels in the lake water column (average of all stations) - 1994

	MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER	
Depth (m)	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**	**Dissolved Oxygen % Saturation**	**Tempera-ture °C**
0	109	12.6	101	14.9	104	18.1	101	17.3	94	13.9	102	9.9	85	7.6
1	109		100		103	18	100	16.9	94	13.9	102		84	
2	109	12.6	100	14.9	96	17.6	96	16.8	93	13.9	101	9.7	84	7.6
3	109		100		91	17.4	93	16.7	92	13.9	100		84	
4	102	12.3	100	14.7	82	17.1	86	16.7	92	13.9	93	9.8	84	7.6
5	102		100		68	16.7	83	16.6	92	13.8	91		84	
6	100	12.3	100	14.2	48	16.4	77	16.5	91	13.8	82	9.7	84	7.5
7	97		91		31	15.6	55	15.5	90	13.8	83		83	
8	94	12	89	14.1	19	14.9	37	13.9	90	13.8	74	9.7	82	7.5
9	92		77	---	19	14.6	---	---	---		---		---	
10	91	11.9	---	---	---	---	---	---	---		---		---	

Table E4 Dissolved oxygen and temperature levels in the lake water colum (average of all stations) - 1995

	APRIL		MAY		JULY	
Depth (m)	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C	Dissolved Oxygen % Saturation	Temperature °C
0	108	9.85	103	15	106	19.8
1	107	9.5	103	14	103	19.6
2	105	9.3	103	13.9	100	19.5
3	104	9.3	101	13.7	94	19.1
4	104	9.2	94	12.7	95	18.9
5	104	9.2	90	11.9	91	18.7
6	104	9.2	87	11.5	27	18.1
7	104	9.2	85	11.3	3	17
8	104	9.2	83	11.2	2	16.7
9	104	8.9	---	---	1	14.1
10	104	8.9	---	---	---	13.8

STATUTORY INSTRUMENTS

S.I. No. 294 of 1989

EUROPEAN COMMUNITIES (QUALITY OF SURFACE WATER INTENDED FOR THE ABSTRACTION OF DRINKING WATER) REGULATIONS, 1989.

Dublin
Published by the Stationery Office

Pl. 6905 Price £1.80

Part II

Surface Water Quality Standards

	Parameters	Unit of measurement	Standards for Categories		
			A1	A2	A3
1.	pH	pH Unit	5.5-8.5	5.5-9.0	5.5-9.0
2.	Colouration (after simple filtration)	mg/l Pt scale	20(o)	100(o)	150(o)
3.	Total suspended solids	mg/l SS	50		
4.	Temperature	^{o}C	25(o)	25(o)	25(o)
5.	Conductivity	$\mu s/cm^{-1}$ at 20 ^{o}C	1000	1000	1000
6.	Odour	(dilution factor at 25^{o}C)	5	10	20
7.*	Nitrates	mg/l NO_3	50(o)	50(o)	50(o)
8.	Fluorides	mg/l F	1	1.7	1.7
9.*	Dissolved iron	mg/l Fe	0.2	2	2
10.*	Manganese	mg/l Mn	0.05	0.3	1
11.	Copper	mg/l Cu	0.05(o)	0.1(o)	1(o)
12.	Zinc	mg/l Zn	3	5	5
13.	Boron	mg/l B	2	2	2
14.	Arsenic	mg/l As	0.05	0.05	0.1
15.	Cadmium	mg/l Cd	0.005	0.005	0.005
16.	Total chromium	mg/l Cr	0.05	0.05	0.05
17.	Lead	mg/l Pb	0.05	0.05	0.05

	Parameters	Unit of measurement	Standards for Categories A1	A2	A3
18.	Selenium	mg/l Se	0.01	0.01	0.01
19.	Mercury	mg/l Hg	0.001	0.001	0.001
20.	Barium	mg/l Ba	0.1	1	1
21.	Cyanide	mg/l CN	0.05	0.05	0.05
22.	Sulphates	mg/l SO_4	200	200(o)	200(o)
23.	Chlorides	mg/l Cl	250	250	250
24.	Surfactants (reacting with methylene blue)	mg/l (laurylsulphate)	0.2	0.2	0.2
25.*	Phosphates	mg/l P_2O_5	0.5	0.7	0.7
26.	Phenols (phenol index) paranitraniline 4-aminoantipyrine	mg/l C_6H_5OH	0.0005	0.005	0.1
27.	Dissolved or emulsified hydrocarbons (after extraction by petroleum ether)	mg/l	0.01	0.2	1
28.	Polycyclic aromatic hydrocarbons	mg/l	0.0002	0.0002	0.001
29.	Total pesticides (parathion, BHC, dieldrin)	mg/l	0.0005	0.0025	0.005
30.*	Chemical oxygen demand (COD)	mg/l O_2			40
31.*	Dissolved oxygen saturation rate	% O_2	>60%	>50%	>30%
32.*	Biochemical oxygen demand (BOD_5) (at 20 °C without nitrification)	mg/l O_2	5	5	7

	Parameters	Unit of measurement	Standards for Categories A1	A2	A3
33.	Nitrogen by Kjeldahl method (except in NO_2 and NO_3)	mg/l N	1	2	3
34.	Ammonium	mg/l NH_4	0.2	1.5	4 (o)
35.	Substances extractable with chloroform	mg/l SEC	0.2	0.4	1
36.	Total coliforms 37 °C	/100 ml	5,000	25,000	100,000
37.	Faecal coliforms	/100 ml	1,000	5,000	40,000
38.	Faecal streptococci	/100 ml	200	2,000	10,000
39.	Salmonella		Not present in 500 ml	Not present in 100 ml	

(o) = See article 5(1)(b)
* = See article 5(1)(d).

Appendix G

STATUTORY INSTRUMENTS

S.I. NO. 293 OF 1988

EUROPEAN COMMUNITIES (QUALITY OF SALMONID WATERS) REGULATIONS, 1988

Dublin
Published by the Stationery Office

Pl.6007 Price £0.75

SECOND SCHEDULE

SALMONID WATER QUALITY STANDARDS

Column 1 Parameter	Column 2 Unit of Measurement	Column 3 Standard
Temperature	°C	Temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone as determined by the local authority) must not - (a) exceed the unaffected temperature by more than 1.5°C, (b) exceed - (i) 21.5°C, or (ii) 10°C, during the period from 1 November to 30 April where species which need cold water for reproduction are present. A thermal discharge must not cause sudden variations in temperature. (Temperature limits to be conformed with for 98% of the time)
Dissolved Oxygen	mg /litre O_2	50% ≥ 9 When the oxygen content falls below 6 mg/litre the local authority must prove that there will be no harmful consequences for the balanced development of the fish population.
pH		$\geq 6 \leq 9$ Artificial pH variations with respect to the unaffected values shall not exceed $\pm$ 0.5 of a pH unit within the limits 6 and 9 provided that these variations do not increase the harmfulness of other substances present in the water. (Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).

Column 1 Parameter	Column 2 Unit of Measurement	Column 3 Standard
Suspended Solids	mg/litre	≤ 25 The standard is expressed as an average concentration over a period of 12 months and does not apply to suspended solids with harmful chemical properties.
BOD_5	mg/litre O_2	≤ 5 Where weed or sewage fungus growths are excessive appropriate measures for control should be taken. (Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).
Nitrites	mg/litre NO_2	≤ 0.05 (To be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).
Phenolic Compounds		Phenolic compounds must not be present in such quantities that they adversely affect fish favour.
Petroleum Hydrocarbons		Petroleum products must not be present in such quantities that they: - form visible film on the surface of the water or form coatings on the beds of water-courses and lakes - impart a detectable "hydrocarbon" taste to fish - produce harmful effects in fish.

Column 1 Parameter	Column 2 Unit of Measurement	Column 3 Standard
Non-ionized Ammonia	mg/litre NH_3	$\leq$ 0.02 (Standard may be exceeded in the form of minor peaks in daytime and, subject to this, be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per months; where sampling is less frequent the standard shall be conformed with by all samples).
Total Ammonium	mg/litre NH_4	$\leq$ 1 subject to conforming with the standard for non-ionized ammonia. (Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).
Total Residual Chlorine	mg/litre HOCl	$\leq$ 0.005 (Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).
Total Zinc	mg/litre Zn	Water Hardness (mg/litre Ca CO_3) | Standard 10 | $\leq$ 0.03 50 | $\leq$ 0.2 100 | $\leq$ 0.3 500 | $\leq$ 0.5 (Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).

Column 1	Column 2	Column 3	
Parameter	Unit of Measurement	Standard	
Dissolved Copper	mg/litre Cu	Water Hardness (mg/litre Ca CO_3)	Standard
		10	$\leq$ 0.005
		50	$\leq$ 0.022
		100	$\leq$ 0.04
		300	$\leq$ 0.112
		(Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples).	