NRA WATER QUALITY 71

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CLASSIFICATION OF RIVER WATER QUALITY

National Rivers Authority

Version 1.0
29 April 1992

PREFACE

In order to protect our water supplies, our wildlife and the centre of much of our recreation, it is important to know the state of our rivers and to assess correctly which rivers have truly recovered and which need improvement.

This report sets out one of the ways in which the quality of rivers in England & Wales will be reported and compared in future. It gives results which will form the baseline against which progress towards cleaner rivers will be measured.

We set out a way of classifying river quality which combines direct measurements of pollution with information on the biological life found in rivers. The classification may be used, as required by the Secretaries of State, for Statutory Water Quality Objectives issued under the 1991 Water Resources Act. It also allows comparisons with the past and ensures a correct ranking of river quality in different parts of England and Wales.

Version 1.0. April 1992

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1. INTRODUCTION AND SUMMARY

1.1 The National Rivers Authority, the NRA, is a public body whose task is to protect and improve the water environment in England and Wales. The NRA was set up under the Water Act of 1989 with duties which include:

> Maintain and improve water quality in **rivers** (as well as streams, canals, lakes, groundwaters, estuaries and coastal waters).

1.2 In 1991 the NRA published the 1990 River Quality Survey for England and Wales[1]. The Survey found that 89% of rivers were of Good or Fair Quality and 2% were Bad. Since 1985 there had been a net downgrading of about 4% in the quality of rivers.

1.3 The quality of individual lengths of rivers was reported according to the classification developed for the former National Water Council (NWC)[2]. The Survey for 1990 will be the last to use the NWC Classification. A new system is required to:

- secure consistency throughout all of England and Wales;
- eliminate the need for subjective judgements;
- control the risk of putting rivers in the wrong class; and,
- provide a scheme which may be used, as required by the Secretaries of State, for the Statutory Water Quality Objectives to be introduced under the 1991 Water Resources Act.

These first two points will ensure that the United Kingdom can make a comparison of river water quality in different parts of England and Wales which is not clouded by differences in procedure.

1.4 In its proposals for Statutory Water Quality Objectives[3], the NRA published the options for a new classification for rivers. The report invited comments on the proposals.

1.5 This report gives details of the new classification and the results of applying it for 1990. The scheme combines direct measurements of pollution with information on the biological life found in rivers. It also has strict rules to define how it is to be applied throughout England and Wales.

1.7 The need for continuity is addressed by applying both the old and new systems to the data collected for 1990. Thus the report on the 1990 Survey compared 1990 with past Surveys using the NWC Classification. The results for the new system are in this report and future changes will be assessed against this baseline.

1.8 The quality defined by the new Classes is a little better than the NWC Classes and this means that only 78% of rivers are placed in the Classes defined as either Good or Fair Quality, 16% were Poor and 2% were Bad.

1.9 For years the unavoidable reality that classification is imprecise has been ignored. For the first time in a report of this kind the risk has been calculated that any river has been placed in the wrong Class. This is a fundamental consideration in deciding whether action is needed to improve water quality. It will also prevent complacency for rivers placed in a good Class.

1.10 The overall risk that a river may be placed in the wrong class is about 18% on average with a maximum of 50%. This is split evenly between the risk of placing the river in a Class which is better than the true Class and the risk of putting the river in a Class which is worse than the true Class.

1.11 There will be an average risk of 25% of declaring wrongly that a river has **changed** Class from one Survey to the next. In future surveys the NRA will calculate this for each site.

2. HISTORICAL BACKGROUND

2.1 The reporting of river classification in England and Wales began in 1970 with the publication by the Department of the Environment of the River Pollution Survey.

2.2 These surveys recorded the general state of rivers and canals. They have been repeated every five years since 1970. They assess progress in maintaining and improving river water quality in England and Wales.

2.3 The classification for 1970 placed rivers in four classes based on the chemical measurement known as the **Biochemical Oxygen Demand (BOD)**. The scheme also used other criteria involving the type of effluents discharged and the number of complaints received.

2.4 The biological quality was also measured for 1970. A comparison of the chemical and biological classifications was reported, but this failed to show the universal relationship which was needed if biological data were to be used to report on the national scale.

2.5 Following the creation of the **Water Authorities** in 1974, the **National Water Council** changed the method of classification[4]. One of the aims was more consistency. Accordingly, from 1978, all the Water Authorities classified their rivers using the new system. In later years, it became the norm to define river quality in terms of the **NWC Class**.

2.6 The NWC scheme was adopted by the Department of the Environment for its River Quality Surveys for 1980 and 1985[2,5]. The Department also asked the NRA to use the NWC Class for the 1990 Survey.

2.7 The main chemical **determinands** used in the NWC Class were the BOD, the **Dissolved Oxygen** and **Ammonia**. These measure the type of pollution caused by discharges like those from sewage treatment works. The Classes were defined by the levels of these determinands which were needed to provide important uses such as fisheries and abstractions for supplies of drinking water.

2.8 In addition, the better quality NWC Classes were expected to meet the standards set up to protect fisheries by the European Inland Fisheries Advisory Commission (EIFAC). These standards are called **EIFAC Standards.**

2.9 The NWC Classification also referred to the **Surface Water Directive** issued by the European Commission. Certain of the Classes were required to meet the standards set out in this Directive.

2.10 It has become the custom to say that in providing attributes like a fishery or a water supply, the river is being **Used**. The fishery and the supply of water are examples of **Uses**. Water quality standards needed to protect a Use are called **Use-related Standards.**

2.11 The NWC Class attempted to provide an **absolute measure** of quality. This meant that rivers were to be compared on a common scale and, in principle, the NWC Class would then show national and regional trends and allow regional comparisons.

2.12 But the NWC Class also indicated the Uses which the river could support, particularly through the EIFAC Standards and the Surface Water Directive.

2.13 One problem was that new Uses, new standards and new Directives were being introduced steadily over the years. If these were incorporated within the NWC Class, the Class would cease to be an absolute measure of quality because not all the standards would apply to all the rivers. Also, if the definition of Class changed over time, the facility would be lost to use the Class to point to trend.

2.14 Recognising this, the former Water Authorities Association recommended a new Class specifically designed to show absolute quality[6]. Rivers would then be checked separately for compliance with Use-related Standards and with the standards in Directives.

2.15 Even after the introduction of the NWC Class, the process by which rivers were given a change of Class varied across the ten former Water Authorities. The main reason for this was statistical. The results of classification were sensitive to the random chance associated with taking samples for chemical analysis (Appendices B and E). This produced a theoretical risk of 30% that a river might be placed in the wrong Class.

2.16 The former Water Authorities adopted various strategies for controlling this error. Some ignored it, others declined to regrade unless the change appeared significant (Appendix B).

2.17 In 1986, in order achieve more harmony, the Water Authorities Association looked at the methods used to put rivers in a Class[7]. The Association felt that for reports on absolute quality and reporting change, the United Kingdom needed a scheme based on a small set of standards which might be expected to remain unchanged over time. The recommendations of the Association provided the starting point for the procedures set out in this report.

THE NRA CLASS

3.1 In its report on Proposals for Statutory Water Quality Objectives[3], the NRA published suggestions for the new classification. This report invited comments, allowing three months for a response.

3.2 Appendix B is a review of the NWC Classification[2,4]. The new system is needed in order to:

- provide an absolute measure of river quality throughout England & Wales;
- eliminate subjectivity in classification;
- secure consistency throughout England and Wales; and,
- control the risk of putting rivers in the wrong Class.

3.3 This present report gives details of the new scheme and reports the results of applying it for 1990. The new Class is called the **NRA Class**. It combines direct measurements of pollution with information on the biological life found in rivers. The chemical standards are in Table 3.1.

Chemical Criteria for the NRA Class

3.4 Although the NRA Class is designed to monitor absolute quality, the chemical standards used to define the better Classes are consistent with the protection of fisheries and reckoned as needed for rivers which are suitable as sources of drinking water.

3.5 A genuine Class A or B is the norm for salmonid fish. Rivers which are truly in Class D or E are unsuitable as sources of drinking water and would not support good and stable fisheries.

Table 3.1: **Chemical Standards for the Classification of Rivers**

Class	River Quality Standards		
	Dissolved Oxygen	Biochemical Oxygen Demand (ATU)	Ammonia
	(% saturation)	(mg/l)	(mgN/l)
	10-percentile	— 90-percentile	—
A	80	2.5	0.2
B	70	4	0.6
C	50	8	2.5
D	20	15	-
E	< 20	-	-

3.6 Appendix B and C describe the use of the data collected for 1990 to assign classes using the standards in Table 3.1. In doing this fixed rules were used throughout England and Wales (Appendix C). A summary of the results is given in Table 3.2.

Table 3.2: **Results of NRA Survey (chemical data only)**

Region	% Length in each Chemical Class				
	A	B	C	D	E
Anglian	1.5	21.9	58.2	16.4	2.0
North West	22.1	19.2	31.5	23.3	3.9
Northumbria	12.6	53.5	22.6	9.8	1.4
Severn Trent	8.5	24.3	47.1	18.0	2.0
South West	33.2	46.8	16.9	2.1	1.0
Southern	10.9	33.1	43.7	10.6	1.8
Thames	9.4	32.2	41.4	15.2	1.8
Welsh	40.8	36.0	17.5	4.5	1.3
Wessex	9.8	34.3	45.1	10.1	.7
Yorkshire	12.3	27.0	31.3	25.3	4.1
England & Wales	16.5	31.1	36.9	13.5	1.9

See Appendix F for lengths in kilometres

3.7 The prime purpose of the criteria in Table 3.1 is to set standards for discharges like those from sewage treatment works and monitor success in achieving them in terms of the impact on rivers.

3.8 This purpose can be undermined because some clean rivers with low velocity would be placed in Classes D or E because of the effect of algae on the measurement of BOD in the laboratory. This distortion was removed. Rivers were not moved into a poorer NRA Class if the only fact indicating this was a high BOD caused not by pollution but by the effect of algae on the laboratory test.

3.9 The NRA Class also includes a biological component. Operating alone, the standards in Table 3.1 allow a river to achieve a good Class but have poor biology because of pollutants not listed in Table 3.1, or because of factors like:

- the effect of acid rain;
- the impact of past mining; or,
- intermittent pollution not detected by sampling for chemical analysis.

3.10 These effects can be covered by including a large number of extra chemicals in the definition of Class. However, it would be inefficient to analyse for these everywhere and a commitment to add new standards would weaken the NRA Class as a measure of absolute quality and change (Appendix B).

Biological Criteria and the NRA Class

3.11 To measure the impact of pollution not covered by Table 3.1 the NRA has used biological data to adjust the Class suggested by the chemical data. Rivers which are chemically clean were not be placed in a good Class if they had poor biology. Similarly, rivers were not placed in a poor Class if the biological quality was excellent. This use of the biological data is called a **Biological Override**.

3.12 The Override depends on the monitoring of small creatures which live on the bed of the river. These are **benthic macroinvertebrates** or, in this report, **invertebrates**.

3.13 The biological life in rivers is different in different rivers even when there are no factors which cause damage. This suggests that it is best to describe the biology in terms of a shortfall from that expected under conditions of good water quality.

3.14 The Department of the Environment developed these ideas using a mathematical model to predict the biological life which should be found in a clean river. The model is called **RIVPACS**, an acronym for River Invertebrate Prediction and Classification System. RIVPACS was developed by the Institute of Freshwater Ecology.

3.15 It turned out that the most generally useful method of summarising the biological data was based on an index which takes its name from the Group which devised it, the Biological Monitoring Working Party. The index is called the **BMWP Score**[5].

3.16 For each site, RIVPACS was used to predict the BMWP Score expected under conditions of no pollution. River quality was then be expressed as the fraction of this prediction formed by the BMWP Score measured during 1990. Such a ratio is called an **Ecological Quality Index** or **EQI** and:

$$EQI = \frac{\text{BMWP Score}}{\text{BMWP Score predicted by RIVPACS}}$$

3.17 A value for the EQI of 1.0 or more indicates that the biological life in the river corresponds to that expected under conditions of excellent water quality. Lower scores indicate that the biological life may be stressed.

3.18 The Biological Override is defined in Table 3.3 and operates as follows. A river whose chemistry placed it in Class C would be downgraded to Class D if its EQI were less than 0.40 and upgraded to Class B if its EQI were more than 1.00. If the EQI were less than 0.20 the river would be downgraded to Class E. A score of more than 1.20 would put it in Class A.

Table 3.3: **Biological Override**

Chemical Class	Average EQI	
	Downgrade	Upgrade
A	< 0.70	-
B	< 0.60	> 1.20
C	< 0.40	> 1.00
D	< 0.20	> 0.80
E	-	> 0.60

The derivation of the Override is discussed in Appendix D.

3.19 The system can be thought of as a Biological Classification based on the values of the EQI set out in Table 3.4. In this the Biological Classes parallel the Chemical Classes defined by Table 3.1. Roughly speaking, if this Biological Class is two grades better than the Chemical Class then the Chemical Class is upgraded by one Class. A similar rule operates for downgrades.

Table 3.4: **Biological Classification**

Class	Average EQI
a	> 0.95
b	> 0.80
c	> 0.60
d	> 0.40
e	< 0.40

3.20 Table 3.5 shows the results of using just the biological data and the the Biological Classification shown in Table 3.4.

Table 3.5 **Results of NRA Survey (biological data only)**

Region	% Length in each Biological Class				
	a	b	c	d	e
Anglian	25.1	18.5	26.7	18.0	11.7
North West	12.9	18.0	21.0	10.1	38.0
Northumbria	27.5	19.5	18.9	13.9	20.2
Severn Trent	12.5	12.9	23.4	24.5	26.7
South West	64.5	18.4	9.3	4.3	3.4
Southern	41.2	19.6	19.2	12.1	7.9
Thames	54.8	9.7	10.8	11.9	12.7
Welsh	44.5	18.1	18.6	12.4	6.4
Wessex	33.1	21.2	22.3	17.0	6.5
Yorkshire	39.1	15.1	12.4	13.1	20.4
England & Wales	31.9	16.9	19.9	15.0	16.4

See Appendix F for lengths in kilometres

3.21 Table 3.6 maps the Chemical Classes defined by Table 3.1 on the Biological Classes defined by Table 3.3. The figures show, for example, that 2.4% of rivers in England and Wales are in Chemical Class B and Biological Class a. Such rivers could be labelled as Class B_a.

Table 3.6: **Comparison of Biological and Chemical Quality**

Lengths of River in Chemical and Biological Classes (km)						
Biological Class (Table 3.3)	Chemical Class (Table 3.1)					
	A	B	C	D	E	Total
a	9.4	15.2	8.2	.9	.1	33.8
b	3.6	6.1	5.7	1.0	.1	16.5
c	2.5	6.4	8.2	1.8	.1	19.1
d	1.0	3.1	7.7	2.5	.4	14.7
e	.5	1.7	6.8	5.9	1.1	15.9
Total	17.1	32.5	36.6	12.0	1.8	100.0

See Appendix F for lengths in kilometres

3.22 Finally, the Biological Override in Table 3.3 and the chemical standards shown in Table 3.1 are combined to produce the NRA Classification and the results shown in Table 3.7.

Table 3.7: **Results of NRA Survey (Chemistry with Biological Override)**

Region	% Length in each Chemical Class				
	A	B	C	D	E
Anglian	5.9	24.9	49.9	16.8	2.4
North West	19.8	18.5	23.9	25.3	12.4
Northumbria	11.9	46.6	20.6	15.3	5.6
Severn Trent	6.9	19.9	41.6	26.3	5.3
South West	37.6	44.0	14.0	3.4	1.0
Southern	17.0	33.6	35.0	13.1	1.3
Thames	30.6	25.1	27.6	14.3	2.5
Welsh	35.7	34.1	20.0	8.1	2.0
Wessex	16.3	29.8	39.5	13.0	1.4
Yorkshire	15.4	22.7	26.1	24.1	11.7
England & Wales	19.8	28.5	31.2	16.3	4.3

See Appendix F for lengths in kilometres

3.23 The effect of the Override is shown in Table 3.8. About 10% of river length was upgraded and 12% was downgraded.

Table 3.8: **Change Introduced by the Biological Override**

Region	% Length Regraded by Biological Data	
	Up	Down
Anglian	15.1	7.6
North West	.0	20.0
Northumbria	3.3	20.7
Severn Trent	3.0	19.8
South West	9.0	2.9
Southern	17.9	8.0
Thames	31.4	6.9
Welsh	5.4	14.6
Wessex	12.6	7.2
Yorkshire	4.5	16.0
England & Wales	10.1	12.2

See Appendix F for lengths in kilometres

3.24 This approach, based on the 90-percentile for chemical data and the EQI for biology, has strong advantages in terms of obtaining a precise classification and in providing a sound statistical basis for deciding whether the class changes in the future (Appendix E). In particular, the Biological Override, like the Chemistry, will function simply and properly no matter what level of biological sampling is employed in future.

3.25 The above summaries cover about 8000 stretches of river. Table 3.9 gives examples of the results for four individual stretches. Similar results are available for all 8000 stretches. The NRA will make these data available to interested parties.

Risk of Mis-classifcation for Individual Rivers

3.26 For the first time in national reports on river quality, this survey has calculated the risk that any stretch of river has been placed in the wrong Class[10]. The risk depends on the frequency of sampling - the more sampling the more confident the assessment of Class. The risk depends also on the true river quality and how close this is to the boundary of the next Class.

3.27 The average risk over all sites is 17% (Appendix E). This is split evenly between the risk of placing the river in a Class which is better than the true Class and the risk of putting the river in a Class which is worse than the true Class.

3.28 Classes A and B are similar and are associated with the same sorts of uses. If they were merged, the average risk of mis-classification would reduce from 17% to 12%.

3.29 Examples are given in Table 3.9. For some stretches, there is almost 100% confidence that the Class is correct. For others the risk of misclassification is close to 50%. For each stretch, Table 3.9 gives the confidence that the true Class is each of Classes A to E[10]. Similar information is given in Table 3.9 for the Biological Classes (Appendix D).

Risk of Wrongly Declaring a Change of Class

3.30 The average risk of 17% may seem large, but it is smaller than the risk of declaring wrongly that a river has **changed** Class from one Survey to the next. Appendix E shows an average risk of 25% in reporting wrongly that class has changed. The extra error arises because two risks of mis-classification are compounded - one for the first Survey and one for the next.

3.31 Appendix E describes how the NRA will calculate explicitly for each site the risk that the reported change of Class may not be a true change. The values calculated for these risks will be borne in mind when considering the need to act to improve water quality. They will also act as a guard against premature celebrations that quality has improved.

Table 3.9: **Examples of Results for a Single Stretches**

Region	nwest
River	SMOKER BK.
Stretch	GALE BK. (LODGE LANE) TO WINCHAM BK. 14.9 km

Chemistry	Mean	Standard Dev.	No. of Samps.	90 %-tile
BOD	2.77	1.46	21	4.62
Ammonia	.41	.52	20	.89
Diss.Ox	89.56	29.11	18	52.25
Override	Value	EQI	No.sam	
Avge.BMWP	19	.151	3	

Confidence Chem.Class	Confidence Over-Class
A 0 %	a 0 %
B 5 %	b 0 %
C 94 %	c 0 %
D 1 %	d 0 %
E 0 %	e 100 %
Class: C	Class: e
NRA Class: E	

Region	thames
River	CHALGROVE BROOK
Stretch	Source - Thame 12.1 km

Chemistry	Mean	Standard Dev.	No. of Samps.	90 %-tile
BOD	1.45	.81	34	2.47
Ammonia	.06	.19	34	.13
Diss.Ox	95.91	15.71	34	75.78
Override	Value	EQI	No.sam	
Avge.BMWP	111	1.207	3	

Confidence Chem.Class	Confidence Over-Class
A 44 %	a 92 %
B 56 %	b 7 %
C 0 %	c 1 %
D 0 %	d 0 %
E 0 %	e 0 %
Class: B	Class: a
NRA Class: A	

Region	wessex
River	MARDEN
Stretch	HAZELAND-CONF WITH AVON 4.7 km

Chemistry	Mean	Standard Dev.	No. of Samps.	90 %-tile
BOD	3.18	1.61	153	5.23
Ammonia	.25	.20	155	.48
Diss.Ox	83.21	15.22	148	63.70
Override	Value	EQI	No.sam	
Avge.BMWP	72	.600	3	

Confidence Chem.Class	Confidence Over-Class
A 0 %	a 0 %
B 0 %	b 0 %
C 100 %	c 99 %
D 0 %	d 0 %
E 0 %	e 1 %
Class: C	Class: c
NRA Class: C	

Region River Stretch	york River Esk Backwood Beck \Little Beck 2.3 km			
Chemistry	Mean	Standard Dev.	No. of Samps.	90 %-tile
BOD	1.33	.70	30	2.22
Ammonia	.11	.10	30	.22
Diss.Ox	90.74	11.29	27	76.27
Override	Value	EQI	No.sam	
Avge.BMWP	173	1.311	3	

Confidence Chem.Class	Confidence Over-Class
A 28 %	a 97 %
B 72 %	b 3 %
C 0 %	c 0 %
D 0 %	d 0 %
E 0 %	e 0 %
Class: B	Class: a
NRA Class: A	

4 STATUTORY WATER QUALITY OBJECTIVES

4.1 The 1991 Water Resources Act, for the first time in the United Kingdom, allows the introduction under statute of a system of Water Quality Objectives. These objectives will serve as the framework for national policy on river quality. The Act places a duty on the Secretaries of State and the National Rivers Authority (NRA) to achieve the Objectives which are set and to continue to protect them thereafter.

4.2 The objectives are stepping-stones towards improving river quality where necessary, or maintaining it at a given level. Each objective will have a defined purpose, including a consideration of the use of the river, and each objective will have a date by which it has to be attained. The achievement of the objectives will be the driving force behind the control of polluting discharges, and other means of controlling river quality.

4.3 Before a Statutory Water Quality Objective can be introduced, the Secretaries of State must set up **Classification Schemes** under Section 82 of the Water Resources Act.

4.4 The Classification Schemes categorise stretches of water according to water quality. The criteria may include:

- general requirements which describe the purpose to which the waters would be put;
- substances which should be present or absent, and limits on the concentrations of substances; or,
- specific requirements on any other characteristics of the water.

4.5 The Secretary of State establishes a Classification Scheme by publishing a **Statutory Instrument**.

4.6 For these Classification Schemes to take effect, they must be incorporated into **Statutory Water Quality Objectives**. Such an Objective is established when the Secretary of State ***Serves a Notice*** on the NRA which specifies:

- the one or more Classification Schemes prescribed under Section 82;
- the stretches of rivers to which the Classification Schemes will be applied; and,
- the date by which the water quality criteria in the Classification Schemes must be met.

4.7 The Secretaries of State may decide to set up the NRA Class as a Statutory Water Quality Objective. They might choose to do this by specifying the chemical or biological components of the NRA Class or the full Class in which chemistry and biology are combined.

4.8 The circumstances under which the NRA Class might be used as a Statutory Water Quality Objective include:

- in conjunction with Objectives for Fisheries, General Ecosystem or Abstraction for Water Supply. The standards in better quality NRA Classes are generally required as a baseline for some of these because they control pollution by sewage and discharges from sewage treatment works. For example:

Use	Class
Salmonid Fishery	A or B
Cyprinid Fishery	B or C
Abstraction for Water Supply	A to C
General Ecosystem	A to C

- to ensure that river quality does not deteriorate whilst the requirements for Uses are sorted out or to ensure no deterioration to the standards associated with poor quality uses.

Appendix A: Membership and Duties of the NRA Working Group on Water Quality Surveys

Membership

John Stoner	NRA, Welsh Region (Chairman)
Alun Gee	NRA, Welsh Region (Technical Secretary)
David Brewin	NRA, Severn Trent Region
John Seager	NRA, National Head Office (from August, 1991)
Peter Chave	NRA, National Head Office (until August, 1991)
Eddie Douglas	NRA, Northumbria Region (from March, 1990)
Tony Edwards	NRA, Yorkshire Region (until March, 1990)
Andrew Haig	Clyde River Purification Board
Roger Sweeting	NRA, Thames Region
Tony Warn	NRA, Anglian Region
Jim Wharfe	NRA, Southern Region

Duties

1. Undertake the national surveys of river water quality.
2. Review the classification systems for rivers, estuaries and coastal waters.
3. Establish the relation between these classification systems and Use-related Objectives,
4. Develop a Use-related classification of rivers and develop classifications for estuaries and coastal waters.
5. Ensure that future surveys can be compared statistically with those of the past.
6. Develop proposals for implementation of the new schemes including mechanisms for rapid reporting.

Appendix B: The Need for a New Classification for Rivers

B.1 This part of the report expands on the need for a new classification.

B.2 With the NWC Class, the details by which rivers were given an upgrade or downgrade of Class varied across the ten former Water Authorities.

B.3 The differences are illustrated in the following figures for areas now covered by the Regions of the NRA. The figures show the percentage of river length which changed NWC Class between 1980 and 1990. The table shows a stable picture in some Regions and volatility in others. Such differences can be explained only by differences in procedure.

Region	1980 to 1985			1985 to 1990		
	Up	Down	Net	Up	Down	Net
Anglian	21	13	+ 8	9	11	- 2
Northumbria	0	3	- 3	1	5	- 4
North West	4	12	- 8	8	11	- 3
Severn Trent	10	7	+ 3	10	8	+ 2
Southern	19	20	- 1	23	16	+ 7
South West	4	45	-41	16	39	-23
Thames	15	18	- 3	18	33	-15
Welsh	22	21	- 1	19	16	+ 3
Wessex	27	10	+17	4	2	+ 2
Yorkshire	8	26	-18	3	8	- 5

B.4 The work done on the 1990 Survey showed differences between the former Water Authorities in:

(a) the statistical methods used to calculate the summaries of water quality (mainly 95-percentiles);

(b) the inclusion or exclusion of any analytical results suspected as being in error because they differed markedly from others from the same site (or because they were caused by extreme events like floods, drought, freeze-up or plant growth)[2];

(c) the sampling frequencies;

(d) the number of years' data used for the assessment;

(e) the inclusion of non-routine samples (like those for pollution incidents and special surveys);

(f) the pooling of data for different sites;

(g) the procedure used to interpolate between sampling points;

(h) the informal use of judgements based on the effects of **algae**, biological data and visual pollution to qualify or overrule the classification suggested by other data;

(i) the weight given to the EIFAC standards;

(j) the status given to the standards in Directives; and,

(k) the allowance made for Statistical Sampling Error when deciding whether a river had changed Class.

Mis-classification

B.5 Unless there is an huge increase in sampling, the summary statistics which are used in classification (such as percentiles) cannot be estimated with a precision which is small in comparison with the ranges of concentration which define the better quality Classes.

B.6 This low precision led to large numbers of spurious and random changes in Class. Faced with this, some of the Water Authorities sought confirmation that apparent changes were real by looking at extra data. Typical cases included:

- sites which 'failed' a standard because of a single bad analytical result at a place where river quality was good according to all the other indicators, e.g. biological data;

- cases where a site 'complied' with all the standards but had no fishery or poor biology; in this case the site might be downgraded;

- sites which failed (or passed) marginally after several years of compliance (or failure) and where there was no obvious cause for the change.

B.7 Other Water Authorities preferred to adhere strictly to the rules of classification but take account of poor precision and other factors as part of the process of deciding whether there was a real need for action to restore river quality. Either way, the former Authorities sensibly tried to avoid the expenditure of effort and money on correcting downgradings caused by chance.

B.8 The NRA has controlled the risk of mis-classification by:

- Using three years' data to calculate percentiles[6,7];

- Re-defining the water quality standards as 90-percentiles instead of 95-percentiles. The 90-percentile is estimated with 35% more precision than the 95-percentile and this makes it easier to detect smaller changes in quality (Appendix E) whilst still preserving much of the strength of the 95-percentile - its ability, as a standard to control the variability of water quality,

- Using the 1990 NRA Survey to establish a baseline - a sound statement of river quality in 1990. After 1990, using this baseline, the problem of poor precision will be managed by showing where the reported changes are statistically significant (Appendix E).

Continuity

B.9 The need for continuity has been addressed by applying both the old and new systems to the data collected in 1990. Thus the NRA has tried to use the old system to compare 1985 and 1990[1]. In the present report, the NRA provides the NRA Classification for 1990. Future changes will be assessed against this baseline.

B.10 The NRA has ensured in its systems for managing data that anyone will be rework past assessments of Class for 1990 if there is ever a need to change the classification again.

Comparison of NWC and NRA Class

B.11 Table B.5 compares the results of the new classification with the NWC Classifications used for the 1990 River Quality Survey. The NRA Classes generally represent cleaner river quality than the NWC Classes.

Table B.5: **Comparison of the NRA Class (chemical data only) and the NWC Class**

NRA Class	% length in Class		NWC Class
A	12	31	1a
B	34	34	1b
C	34	23	2
D	17	10	3
E	3	2	4

Table B.5: **Comparison of the NRA Class and the NWC Class**

NRA Class	% length in Class		NWC Class
A	19	31	1a
B	29	34	1b
C	30	23	2
D	16	10	3
E	5	2	4

B.12 The reason that the NRA Class defines better water quality than the corresponding Class under the NWC Scheme lies in the fact that NRA Scheme has been stripped of the judgements which were a part of the NWC Scheme (Appendix B). These were a legitimate part of the NWC Scheme but cannot be used in standards which might be used as Statutory Water Quality Objectives.

B.13 Also, in transforming from the 95-percentile standards of the NWC Scheme to the 90-percentiles in the NRA Scheme, the NRA tried to make sure that the two sets of standards were equivalent.

Table B.1: **NRA Classification for River Quality**

NRA Class	Quality Criteria	Likely Potential Uses
A Good Quality	■ 10-percentile Dissolved Oxygen Saturation greater than 80% ■ 90-percentile Biochemical Oxygen Demand not greater than 2.5 mg/l ■ 90-percentile Ammonia not greater than 0.2 mgN/l	■ Abstractions for potable supply and all other abstractions ■ Salmonid and other high class fisheries ■ Pristine biology
B Good Quality	■ 10-percentile Dissolved Oxygen Saturation greater than 70% ■ 90-percentile Biochemical Oxygen Demand not greater than 4 mg/l ■ 90-percentile Ammonia not greater than 0.6 mgN/l	■ Rivers whose quality is less than Class A but which are usable substantially for the same purposes. ■ Good biology
C Fair Quality	■ 10-percentile Dissolved Oxygen Saturation greater than 50% ■ 90-percentile Biochemical Oxygen Demand not greater than 8 mg/l ■ 90-percentile Ammonia not greater than 2.5 mgN/l	■ Generally suitable for potable supply after advanced treatment ■ Supporting reasonably good Cyprinid Fisheries ■ Fair biology
D Poor Quality	■ 10-percentile Dissolved Oxygen Saturation greater than 20% ■ 90-percentile Biochemical Oxygen Demand not greater than 15 mg/l ■ Ammonia inferior to Class C	■ Rivers which are polluted to an extent that fish are absent or only sporadically present ■ May be used for a low grade abstraction for industry ■ Poor biology
E Bad Quality	Waters which are inferior to Class D	■ Rivers which are very polluted and which may cause nuisance ■ Impoverished biology

The Biochemical Oxygen Demand refers to the 5-day carbonaceous determination performed in the presence of **Allyl Thio Urea (ATU).**

The process of classification is imprecise. In interpreting the above it should be borne in mind that there is a risk of 9% that the river has been placed in a Class which is better than the true Class and a risk of 9% that the river has been placed in a Class which is worse than the true Class.

Appendix C: **Putting a River in a Class**

C.1 In fixing a Class to a river the NRA followed the following procedure throughout England & Wales:

- For each sampling site, the NRA assigned the stretch of river which the site could characterise.
- If the site fell into a Class, then the entire stretch was given that Class.
- Only the results from the routine, predetermined sampling programmes were used.
- Within these programmes, all the chemical results collected over the three years 1988-90 were included. No **outliers** were excluded.
- Results qualified as "less-than" were halved. Results given as "greater-than" were taken as the value specified.
- A standard **Parametric Method** (**Method of Moments**, described below) was used to estimate percentiles for the chemical determinands.
- The estimates of the percentiles were compared with the standards in Table 3.1. Class was assigned according to the worst determinand.
- All the biological results collected in 1990;

C.2 The NRA then assembled a database which included:

- the name of the reach;
- category of river flow (as defined for past Surveys);
- the length of the reach (km);
- the upstream map reference;
- the downstream map reference;
- the name of the chemical sampling point;
- the Grid Reference for the chemical sampling point;
- the 1990 NRA Class for the reach;
- whether the BOD is Exempted because of the effect of algae on the chemical test;
- the mean, standard deviation and 90-percentile BOD;
- the mean, standard deviation and 90-percentile Ammonia;
- the mean, standard deviation and 10-percentile Dissolved Oxygen;
- the number of chemical samples used in the assessment of each of the above;
- the name of the biological sampling point (if any);

- the BMWP Score and the RIVPACS prediction;
- the ASPT Score and the RIVPACS prediction;
- the number of samples used to compute the biological scores.

Estimation of Percentiles

C.3 For Dissolved Oxygen a **Normal Distribution** was assumed. Given the mean, m, and the standard deviation, s, an estimate of the 10-percentile is q in[8]:

$$q = m - 1.2816\ s \qquad [C.1]$$

Negative value of q were set to zero.

C.4 A **Log-normal Distribution** was assumed for the **Biochemical Oxygen Demand** and **Ammonia**. The values of m and s were converted to the values for the logarithms of the data using the **Method of Moments**:

$$S = \sqrt{[ln\ (1 + s^2/m^2)]}$$
$$M = ln\ [m\ /\ \sqrt{(1 + s^2/m^2)}]$$

C.5 M and S are estimates of the mean and standard deviation of the logarithms of the data. The characters, *ln*, denote the natural logarithm. The 90-percentile is estimated as the exponential of *(M + 1.2816 S)*:

$$q = e^{(M + 1.2816\ S)} \qquad [C.2]$$

Example:	$m = 2.0;\ s = 1.0$ $S = \sqrt{[ln\ (1 + 0.25)]} = 0.4724$ $M = ln\ [m\ /\ \sqrt{(1 + 0.25)}] = 0.5816$ $q = e^{(0.5816 + 1.2816*0.4724)}$ $= 3.28$

APPENDIX D: Biological Data

D.1 The data used for the Biological Override were obtained by monitoring the presence and absence of the types of small creatures like insects and snails which live on the bed of the river. These animals are the **benthic macroinvertebrates**.

D.2 These invertebrates live in continuous contact with river water. If the water is polluted, even for only a few minutes, some or all may die. It may be several weeks before the health and population of all the different types are restored. This means that biological data provide evidence of pollution which may have been missed by chemical monitoring.

D.3 In chemical monitoring, the river will be visited 12 times a year and the sample collected for analysis in the laboratory can say little about pollution which occurred since the last sample was taken. Also, the range of chemicals is large, and it is uneconomic to measure more than a few dozen routinely in the laboratory.

D.4 Because some animals respond differently to different chemicals, the biological data may give a clue about the types of chemical to look for. The NRA can then monitor these and then set about controlling any sources of pollution.

Summary Statistics for Biological Data

D.5 There are thousands of different species of invertebrate and it has proved useful to group these into Families, or **Taxa**. A key piece of information provided by monitoring is the number of different Taxa found at a site. A high **Number of Taxa** is an indication of healthy biology and that pollution or other forms of stress are absent.

D.6 Some animals are more susceptible than others to pollution and so the presence of sensitive creatures is a sign that water quality is good. This fact was taken into account by the **Biological Monitoring Working Party** (BMWP), when it set up a method of summarising biological information in the form of a simple index. This became known as the **BMWP Score**.

D.7 This system assigns points to each Taxa according to its sensitivity to pollution. For example, most mayfly nymphs and caddis larvae score ten points, water beetles score five, molluscs three, and worms, one. The BMWP Score for a site is the sum of all the scores of all the Taxa found.

D.8 Although the weightings in the BMWP Score were designed to reflect the impact on biology of pollution by organic wastes (such as those from sewage effluents), the Score will respond to most types of pollution.

D.9 A third summary statistic, the **Average Score per Taxon**, or **ASPT**, is the BMWP Score divided by the Number of Taxa. This gives a measure of the average sensitivity to pollution, of the families found at a site.

The RIVPACS Model

D.10 The biological life in rivers is different in different rivers even when there are no factors which cause damage. This suggests that it is best to describe the biology in terms of a shortfall from that expected under conditions of good water quality. Damage to the biological life could be assessed by comparing the measured biology with the biology predicted for pristine conditions of water quality.

D.11 The Department of the Environment developed this idea using a mathematical model to predict the biological life which should be found in a clean river. The model is called **RIVPACS**, an acronym for River Invertebrate Prediction and Classification System. RIVPACS was developed by the Institute of Freshwater Ecology.

D.12 RIVPACS was based on a study of the invertebrates found in 400 clean-water sites in Great Britain. In this, information on the invertebrates was cross-matched with data on:

- the width of the channel;
- the depth of the water;
- the types of material which form the river bed (boulders, pebbles, sand, clay or silt);
- the **alkalinity** of the river water;
- the Longitude and Latitude;
- the altitude of the site;
- the distance from the start of the river to the site;
- the slope of the adjacent terrain;
- the river flow;
- the air temperature.

D.13 The result was a method by which these physical data could be used by RIVPACS to predict the types of invertebrates which should be found under conditions of good water quality, at any site in the United Kingdom.

D.14 The form of the Biological Override was based on calculations in which the ASPT, the BMWP Score and the Number of Taxa for each site in England & Wales were mapped onto the Chemical Class (Table 3.1 in the main text).

D.15 It turned out that in terms of showing water quality in rivers, the most generally useful method of summarising the biological data was based on the **BMWP Score**[5].

D.16 For each site, RIVPACS was used to predict the BMWP Score expected under conditions of no pollution. River quality was then be expressed as the fraction of this prediction formed by the BMWP Score measured during 1990. Such a ratio is called an **Ecological Quality Index** or **EQI** and:

$$EQI = \frac{\text{BMWP Score}}{\text{BMWP Score predicted by RIVPACS}}$$

D.17 The precise numeric form of Override was based on calculations in which the average value of the EQI for each site in England & Wales was mapped onto the Chemical Class defined by Table 3.1. Each Chemical Class was characterised by a range of biological scores. The values of the EQI which embraced the middle 70% of the biological scores for each Chemical Class were used as the action levels to upgrade and downgrade the Chemical Class in the Biological Override. The choice of of 70% was based on a detailed look at the quality of thousands of kilometres of rivers throughout England & Wales.

Table D.1: **Biological Override based on the EQI**

Chemical Class	Average EQI	
	Downgrade	Upgrade
A	< 0.70	-
B	< 0.60	> 1.20
C	< 0.40	> 1.00
D	< 0.20	> 0.80
E	-	> 0.60

D.18 The Biological Override operates as follows. A river whose chemistry placed it in Class C would be downgraded to Class D if its EQI were less than 0.40 and upgraded to Class B if its EQI were more than 1.00. If the EQI were less than 0.20 the river would be downgraded to Class E. A score of more than 1.20 would cause a move to Class A.

D.19 The system can be thought of as a Biological Classification based on the values of the EQI set out in Table D.2. In this the Biological Classes parallel the Chemical Classes defined by the standards in Table 2.1. Roughly speaking, if this Biological Class is two grades better than the Chemical Class then the Chemical Class is upgraded by one Class. A similar rule operates for downgrades.

Table D.2: **Biological Classifications based on EQI**

Class	Average EQI
a	> 0.95
b	> 0.80
c	> 0.60
d	> 0.40
e	< 0.40

Sampling

D.20 The method of sampling was that described in the RIVPACS Manual[9].

Risk of Mis-classification

D.21 The risk of mis-classification was calculated on the assumption that the EQI was estimated with a precision of ± 25%. Examples are given in Tables 3.9 in the main text.

Appendix E: Statistical Background

E.1 This Annex discusses the errors which stem from the use of sampling to estimate river water quality and assess class. It also describes the way the NRA will assess whether Class has changed.

E.3 River quality is monitored mainly by getting trained staff to make regular visits to carefully selected sites. These officers check for signs of damage to the river and look for evidence of a risk of damage. They also perform one or two simple measurements at the river bank and take a sample of the river water or the biological life within it.

E.4 This sample of water is analysed in a laboratory for a range of 10 to 100 chemical determinands depending on the circumstances. The selected sites, or sampling points, are, on average, spaced at 6 to 10 kilometres and they are sampled, as a rule, at least monthly.

E.5 The NRA takes immediate action if any of this activity reveals anything of concern, but in nearly all cases the results cause no immediate worry and they are archived so that they can be assessed later for evidence of longer term problems. This subsequent analysis may also lead to action to improve water quality, in particular to tighter standards on discharges, to increased surveillance, and to negotiations with potential polluters.

Compliance and Standards

E.6 The risk of damage is assessed by comparing the measurements of water quality with river quality standards (including those which define the NRA Class). If the measured water quality is better than the standard the river has complied.

E.7 The standards used for the assessment of longer term effects have a margin of safety built into them so that, for the most part, one or two failed samples forewarns of a risk, but need not cause panic or require emergency action.

E.8 This is achieved by using percentiles as standards. A percentile is a value which is exceeded for a specified proportion of time. The 90-percentile is exceeded for 10% of the time. When the 90-percentile is used as a standard it specifies a level of quality which must be met for at least 90% of the time.

E.9 The system works as follows. A toxicity test may show that a standard of 10 mg/l kills fish. This would be compatible with a 90-percentile of 2.5 mg/l so long as fish are observed to thrive in rivers where this standard is achieved. The risk of seeing levels at 10 mg/l will be acceptably small if the river complies with 2 mg/l for 10% of the time. Action is needed if the river fails for more than 10% of the time. In nearly all cases, this advance warning ensures that action can be completed before real damage occurs.

E.10 Some sites may be lucky and fail the percentile standard yet escape real damage. A small number may even be unlucky and real damage may follow or even anticipate the hard evidence of non-compliance. Pollution control is all about reducing the general risks of damage until they are acceptably small everywhere.

Sampling and Sampling Error

E.11 Water quality is highly variable and only a limited number of samples can be taken at each site. This produces a risk that the NRA will sometimes fail to notice that river quality is bad. This would arise if the worst quality just happened to occur, through chance, at times when no sample was taken.

E.12 This effect of chance is substantial, but the risk of error is aggravated if there is any tendency for poor quality to occur at night or weekends, and if sampling is restricted to normal working hours.

E.13 In practice, the effect of these loopholes is minimised because sampling staff inspect the river for evidence of pollution and the NRA also monitors the quality of discharges. Also, biological sampling provides an indicator of recent pollution because the river life, once damaged, requires time in which to recover. This damage can usually be detected by the biologist. Finally, critical sites will be subjected to continuous monitoring for a few key indicators of water quality, and the NRA plans to take a proportion of its samples outside normal working hours.

E.14 Similarly, it is also inevitable that the NRA will sometimes obtain, for reasons of luck, a set of samples in which river quality tended to be bad **only** when sampled. This might produce the appearance of non-compliance in a river which truly achieved its 90-percentile standard (by failing no more that 10% of the time).

E.15 The risk of drawing a wrong conclusion from sampling can be calculated using the science of Statistics. The uncertainty stemming from a selected number of samples is called **Sampling Error**. It is quantified by calculating **Confidence Limits**.

E.16 For a start the data are not 100% accurate because of errors in chemical analysis. The more serious doubt lies in the element of luck introduced by the use of sampling itself. Usually, the latter is so big that those in chemical analysis can be ignored. ***

Confidence Limits

E.17 Suppose 36 samples collected at a site give a 90-percentile concentration of 2.04 mg/l. This is a precise arithmetic result from the 36 samples. It is not, however, a precise estimate of the true 90-percentile at the site - it is only an approximate estimate. To calculate the true 90-percentile requires continuous accurate monitoring. Had the samples been taken on different dates it is highly improbable that this 90-percentile would also have been 2.04 mg/l.

E.18 The range of these possible estimates of the percentile defines the error in the particular value which we obtained from any one set of 36 samples. The error is estimated by calculating Confidence Limits. This means that in addition to the estimate, say 2.03, a pair of confidence limits is calculated, say 1.03 and 3.13 which span the range within which the true 90-percentile is expected to lie[8,10].

E.19 It is common to calculate 95% confidence limits. To persist with the above example, this means that 1.03 and 3.13 are 95% confidence limits on the estimate of the 90-percentile, 2.04. There was a chance of only 5% that the true 90-percentile was less than 1.03 but that, through luck, the samples gave a value as high as 2.04. Similarly there is a chance of only 5% that the true 90-percentile was greater than 3.13 but that, through luck, the samples gave a value as low as 2.04.

E.20 If high concentrations are bad, the lower confidence limit is called the **Optimistic Confidence Limit**. The upper limit is then the **Pessimistic Confidence Limit**. A pair of 95% confidence limits is said to give the 90% **Confidence Interval**: there is a chance of 10% that the true 90-percentile lies outside this range.

E.21 It follows that::

- if the standard is bigger than the Pessimistic Confidence Limit there is more than 95% confidence that the river passed the standard was met;
- if the standard is less than the Optimistic Confidence Limit there is more than 95% confidence that the river failed the standard;
- where the standard lies between the Confidence Limits it is impossible to declare Compliance or Failure with at least 95% confidence. If decisions are made despite this conclusion there is a risk of between 5% and 50% that we shall be wrong.

E.23 The gap between the Confidence Limits widens as the sampling is decreased[8,10]. When the number of samples is small the gap may be so wide as to preclude a sensible statement of Compliance or Failure. Conversely extra sampling increases the chances of detecting small degrees of Compliance, Failure or change.

Effect of Sampling Error on Classification

E.24 The procedures discussed in Paragraphs 26-30[8,10] have been used to calculated the average uncertainty stemming from the use of 36 samples to estimate percentiles. This gives:

Determinand	90% Confidence Interval
BOD	- 16% to + 28%
Ammonia	- 27% to + 53%
Dissolved Oxygen	- 6% to + 9%

E.25 A particular site with an estimated 90-percentile BOD of 3.3 mg/l would appear to be in in Class B because 3.3 lies between the class limits of 2.5 and 4 mg/l. However this site will generally have, with 36 samples, a Confidence Interval which is wider than the boundaries of Class B. This means that it is uncertain that the river is really in Class B. Ignoring small probabilities that the river is placed in Class A or D, the site will typically have the following probabilities of being classified:

B: 70%	C: 30%

There is a chance of 30% of wrongly reporting the Class.

E.26 This error is even larger when assessing whether a river has changed Class. In a first period, the percentile might be in Class B but the confidence limits could show:

Confidence of B	70%
Confidence of C	30%

which is recorded as Class B. In the next period, the data could show:

Confidence of B	40%
Confidence of C	60%

which is registered as Class C. Over the two periods this looks like a slip from Class B to Class C but the range of possibilities is:

From B to C	42%
From B to B	28%
From C to C	18%
From C to B	12%

E.27 So there is a strong possibility, 58%, that the reported deterioration from B to C did not really happen. There is a small chance, 12%, that quality actually improved (but was recorded as a downgrading).

E.28 The practical consequence of these effects is that the reported Class can change back and forth randomly, every year or so. The effect on the large number of sites in England and Wales is calculated by the **CLass Allocation Model**, CLAM[11].

E.29 Table E.1 shows the results of CLAM in terms of the risk of placing a river in the wrong chemical class. Two sets of figures are given side-by-side, one for the numbers of sites and a second for the percentages.

E.30 Table E.1 shows, for example, that of 2393 of sites which are truly in Class B, 174 will be placed wrongly in Class A and about 265 will be placed wrongly in Class C. A tiny proportion, 3 sites, will be placed wrongly in Class D.

E.31 A handful of sites, 1 in every 1000, are placed wrongly two Classes outside their true Class.

Table E.1: **Risk of Error in Classification**

True Class	Assigned Classes (%) A	B	C	D	E	% Sites in True Class	Assigned Class A	B	C	D	E	Total Sites in True Class
A	14.22	2.24	.03	.00	.00	16.48	1106	174	2	0	0	1282
B	2.84	24.48	3.45	.00	.00	30.76	221	1904	268	0	0	2393
C	.04	3.41	29.34	2.29	.01	35.08	3	265	2282	178	1	2729
D	.00	.04	1.85	12.41	.48	14.77	0	3	144	965	37	1149
E	.00	.00	.01	.51	2.38	2.91	0	0	1	40	185	226
	17.10	30.16	34.67	15.21	2.87	100.00	1330	2346	2697	1183	223	7779
	% sites in Assigned Classes						Total sites in Assigned Classes					

% Risk of Mis-classification = 17.2 (up 8.7; down 8.5)

E.32 The risk that a river may be placed in the wrong class is an average of 17%. This is split evenly between the risk of placing the river in a Class which is better than the true Class and the risk of putting the river in a Class which is worse than the true Class. Table 3.9 gave examples of the errors for particular sites.

E.33 If Classes A and B were merged, the overall risk of mis-classification would reduce to an average 12%.

Risk of Error in Assessing Change of Class

E.34 Table E.2 shows an average risk of 25% in reporting wrongly that class has changed from one Survey to the next. This error would apply if no steps are taken to control the errors introduced by the chance element in sampling.

Table E.2: **Risk of Error in Assessing Change of Class**

Class	A	B	C	D	E	Sites in Survey 2 (%)	A	B	C	D	E	Sites in Survey 2
A	14.78	4.12	.17	.00	.00	19.07	1040	290	12	0	0	1342
B	3.67	21.10	4.48	.01	.00	29.26	258	1485	315	1	0	2059
C	.09	5.23	25.39	2.57	.06	33.34	6	368	1787	181	4	2346
D	.00	.06	3.10	11.54	.84	15.53	0	4	218	812	59	1093
E	.00	.00	.04	.70	2.06	2.80	0	0	3	49	145	197
	18.53	30.51	33.18	14.82	2.96	100.00	1304	2147	2335	1043	208	7037
	Class in Survey 1 (%)						Class in Survey 1					

% Risk of Declaring Change where none has occurred = 25.1 (up 12.9; down 12.2)

Effect of Percentile on Precision

E.35 If the Class-limiting standards are defined not as 90-percentiles but as 95-percentiles the average risk of mis-classification increases from 17 to 26%. Similarly the average risk of wrongly reporting change increases from 25 to 31%. The improvement in precision is the reason for the switch to to 90-percentile in defining the NRA Class (Table 3.1).

Confidence of Assigning the Correct Class

E.36 To control the errors the NRA could use standard statistical techniques for assessing whether class has changed significantly[8,10].

E.37 In testing for an upgrade of Class the Pessimistic Confidence Limit on the estimate of the 90-percentile is estimated by calculating t_u as:

$$t_u = 1.082 + 3.735 / \sqrt{n}$$

where n is the number of samples. The value of t_u is then used in place of 1.2816 in Equations [C.1] or [C.2] in Appendix C.

E.38 The river is upgraded if the Pessimistic Limits for all determinands are better than the Class Limits a Class which is better than that assigned last time.

E.39 For the downgrade test the Optimistic Confidence Limit is calculated from:

$$t_d = 1.206 - 1.503 / \sqrt{n}$$

E.40 The river downgraded to a new Class if the Pessimistic Limit for any determinands is worse than the Class Limit for that Class.

Table E.3: **Risk of Error in Assessing Change of Class**

Class	A	B	C	D	E	Sites in Survey 2 (%)	A	B	C	D	E	Sites in Survey 2
A	17.05	.71	.00	.00	.00	17.76	1271	53	0	0	0	1324
B	.21	28.66	.66	.00	.00	29.53	16	2136	49	0	0	2201
C	.01	.75	33.23	.42	.00	34.41	1	56	2477	31	0	2565
D	.00	.00	.55	14.76	.11	15.41	0	0	41	1100	8	1149
E	.00	.00	.00	.15	2.74	2.88	0	0	0	11	204	215
	17.28	30.12	34.44	15.32	2.84	100.00	1288	2245	2567	1142	212	7454
	Class in Survey 1 (%)						Class in Survey 1					

% Risk of Declaring Change where none has occurred = 3.6 (up 1.7; down 1.9)

E.41 The overall risk that a river will be said to change Class when no change has truly occurred is an average of 4%. This is split evenly between the risk of wrongly upgrading and a risk of wrongly downgrading. There is almost zero risk of wrongly regrading by two Classes.

E.42 A problem with this approach in that there is no way of avoiding the high of mis-classification which will have occurred for the first Survey. The CLAM Model shows that a river placed in the wrong Class in 1990 will tend to remain locked in their 1990 Class because the data are unable to show with sufficient confidence that the Class has changed.

E.43 For this reason it is best to live with the high risk (an average of 25% that river is declared wrongly to have changed Class). At the same time it is important to calculate explicitly for each site the risk that the reported change of Class may not be a true change. This can work as follows.

E.44 The results for 1990 might show for a particular site that there was 65% confidence that the river was Class B but that there was 30% and 5% confidence that the true Class was C or A respectively:

1990	A	B	C	D	E
	5	65	30	0	0

The result for 1995 might suggest a slip to Class C:

1995	A	B	C	D	E
	2	30	68	0	0

E.45 The results for 1990 and 1995 are put together in Table E, there is confidence of 44% that the river has truly declined from Class B to C. This is the most likely history for this river though there is a confidence of 40% that no change of Class has occurred, confidence of 11% that the Class improved, and 49% that Class changed for the worse.

Table E.4: **Risk of Error in Assessing Change of Class**

Confidence of Classification (%)							
		in 1995					
	A	–	2	3	–	–	5
in	B	1	20	**44**	–	–	**65**
1990	C	1	9	20	–	–	30
	D	–	–	–	–	–	0
	E	–	–	–	–	–	0
		2	30	**68**	0	0	100

E.46 These levels of confidence should be borne in mind when considering the need to act to improve water quality and as a guard against premature celebrations that quality has improved.

APPENDIX F: **Supporting Tables**

Table F3.2: **Lengths of River in NRA Chemical Classes**

Region	Length in each Chemical Class (km)					
	A	B	C	D	E	Total
Anglian	70.2	1014.9	2693.9	759.4	94.1	4632.5
North West	715.9	621.9	1018.7	755.9	125.6	3238.0
Northumbria	171.2	724.0	306.4	132.3	19.5	1353.4
Severn Trent	509.4	1466.7	2840.2	1086.9	122.2	6025.4
South West	1350.4	1906.2	688.0	87.4	39.5	4071.5
Southern	239.0	728.2	962.7	233.6	39.0	2202.5
Thames	333.3	1141.1	1467.4	537.6	62.5	3541.9
Welsh	1713.3	1510.7	736.9	188.1	53.1	4202.1
Wessex	263.8	927.2	1219.7	273.3	19.9	2703.9
Yorkshire	280.9	616.1	714.7	578.2	92.5	2282.4
England & Wales	5647.4	10657.0	12648.6	4632.7	667.9	34253.6

See Table 3.2 in Section 3 for percentage lengths

Table F3.5 **Results of NRA Survey (biological data only)**

Region	Length in each Chemical Class (km)					
	a	b	c	d	e	Total
Anglian	2130.1	1571.9	2268.5	1531.9	993.1	8495.5
North West	546.0	758.0	886.7	425.6	1602.0	4218.3
Northumbria	723.3	513.9	497.1	366.0	532.6	2632.9
Severn Trent	666.2	688.9	1249.9	1310.5	1423.6	5339.1
South West	1441.4	411.6	208.0	96.0	77.0	2234.0
Southern	868.5	413.8	404.2	254.3	166.0	2106.0
Thames	1881.9	334.5	370.6	408.8	436.6	3432.4
Welsh	2030.9	825.2	847.5	567.0	294.0	4564.6
Wessex	823.1	527.3	553.6	421.6	161.2	2486.8
Yorkshire	1193.9	460.7	378.6	399.6	623.9	3056.7
England & Wales	12305.3	6505.8	7664.7	5781.3	6310.0	38567.1

See Table 3.5 in Section 3 for percentage lengths

Table F3.7: **Results of NRA Survey (Chemistry with Biological Override)**

Region	Length in each Chemical Class (km)					
	A	B	C	D	E	Total
Anglian	272.8	1155.2	2311.9	780.1	112.5	4632.5
North West	642.4	599.4	774.9	818.2	403.1	3238.0
Northumbria	160.7	630.1	279.4	207.5	75.7	1353.4
Severn Trent	417.0	1198.6	2503.9	1584.1	321.8	6025.4
South West	1531.8	1791.2	570.5	137.7	40.3	4071.5
Southern	373.8	740.3	771.2	289.3	27.9	2202.5
Thames	1082.2	888.9	977.3	506.7	86.8	3541.9
Welsh	1500.8	1434.8	839.9	341.6	85.0	4202.1
Wessex	440.0	805.0	1067.5	352.5	38.9	2703.9
Yorkshire	351.0	518.2	596.6	549.4	267.2	2282.4
England & Wales	6772.5	9761.7	10693.1	5567.1	1459.2	34253.6

See Table 3.7 in Section 3 for percentage lengths

Table F3.8: **Change Introduced by the Biological Override**

Region	Length (km) Regraded by Biological Data	
	Up	Down
Anglian	698.7	354.2
North West	.0	647.1
Northumbria	44.7	280.8
Severn Trent	178.6	1194.5
South West	368.0	116.4
Southern	394.8	175.3
Thames	1112.4	245.9
Welsh	226.2	613.5
Wessex	341.7	194.3
Yorkshire	101.8	364.1
England & Wales	3466.9	4186.1

See Table 3.8 in Section 3 for percentage lengths

Table F3.9: **Comparison of Biological and Chemical Quality**

Lengths of River in Chemical and Biological Classes (km)						
Biological Class (Table 3.3)	Chemical Class (Table 3.1)					
	A	B	C	D	E	Total
a	2647.9	4270.9	2294.0	243.5	21.0	9477.3
b	1015.7	1705.3	1606.6	267.6	32.0	4627.2
c	704.9	1808.6	2291.4	512.5	33.3	5350.7
d	288.7	865.3	2167.6	690.6	104.1	4116.3
e	128.6	463.8	1913.2	1644.8	320.5	4470.9
Total	4785.8	9113.9	10272.8	3359.0	510.9	28042.4

Table F3.9: **Lengths of River Monitored**

Number of Chemical Samples	Number of Biological Samples				
	None	1	2	3	Total
None	5990.4	2155.0	729.7	6044.9	14920.0
From 1 to 9	491.4	586.5	55.7	1078.1	2211.7
From 10 to 15	1856.4	494.8	145.7	3147.7	5644.6
From 16 to 25	1690.4	266.9	149.2	4531.7	6638.2
From 26 to 40	1945.8	381.7	719.0	12276.4	15322.9
More than 40	755.0	120.6	258.2	5425.3	6559.1
Total	12729.4	4005.5	2057.5	32504.1	39063.2

GLOSSARY OF TERMS

Allyl Thio-Urea (ATU)	See Biochemical Oxygen Demand.
Algae	Simple microscopic plants that lack true stems but which are capable of photosynthesis. Algae occur in water and are often discussed in the context of Eutrophication (ibid).
Ammonia	A chemical found in water often as the result of pollution by sewage effluents. It is widely used to characterise water quality. High levels of Ammonia affect fisheries and abstractions for potable water supply.
ASPT	A summary statistic to describe the results of monitoring rivers for the presence of benthic macroinvertebrates (ibid). An acronym for Average Score per Taxon (ibid). The Score refers to the BMWP Score (ibid). (*** check ***).
Benthic	Pertaining to the bed of a river.
BMWP; BMWP Score	BMWP is an acronym for Biological Monitoring Working Party. Some invertebrates are more susceptible than others to pollution and so the presence of sensitive creatures is a sign that water quality is good. This fact was taken into account by the BMWP, when it set up a method of summarising biological information in the form of a simple index. This became known as the **BMWP Score**. This system assigns points to each Taxa according to its sensitivity to pollution. For example, most mayfly nymphs and caddis larvae score ten points, water beetles score five, molluscs three, and worms, one. The BMWP Score for a site is the sum of all the scores of all the Taxa found.
BOD and BOD(ATU) Biochemical Oxygen Demand	A measure of the amount of oxygen consumed in water, usually by organic pollution. Oxygen is vital for life so the measurement of the BOD tests whether pollution could affect aquatic animals. The value can be misleading because much more oxygen is taken up by ammonia in the test than in the natural water. This effect is suppressed by adding a chemical (Allyl Thio-Urea) to the sample of water taken for testing. Hence BOD(ATU).
Biological Classification	A way of placing waters in categories according to the biological life observed from monitoring. Data on macro-invertebrates have long been used for this purpose.

Chemical Classification	A way of placing waters in categories according to assessments of water quality based on measurements of the amount of particular chemicals in the water (especially BOD, Dissolved Oxygen and Ammonia).
Chlorophyll	Group of pigments (mostly green) found in plants by which the energy of sunlight is trapped and used to build up complex materials from water and carbon dioxide.
Compliance Assessment	A procedure applied to the results of a monitoring programme to determine whether a water has met its Quality Standards (ibid).
Consent	A statutory document issued by the NRA which defines the legal limits and conditions on the discharge of an effluent to a water.
Controlled Waters	All rivers, lakes, groundwaters, estuaries and coastal waters.
Cyprinid Fish	Coarse fish like roach, dace and bream.
Dangerous Substances	Substances defined by the European Commission as in need of special control because of they are toxic, bioaccumulate and are persistent. Subjects of the Dangerous Substances Directive. The substances are classified as List I or List II (ibid).
Directive	A type of legislation issued by the European Community which is binding on Member States in terms of the results to be achieved but which leaves to Member States the choice of methods.
Dissolved Oxygen	The amount of oxygen dissolved in water. Oxygen is vital for life so this measurement is a test of the health of a water. Used to classify waters.
Determinand	A general name for a characteristic or aspect of water quality. Usually a feature which can be described numerically as a result of scientific measurement.
EIFAC	An acronym for the European Inland Fisheries Advisory Commission.
Eutrophic	A description of water which is rich in nutrients. At worst, such waters are sometimes beset with unsightly growths of algae (ibid).

Eutrophication	The process of nutrient enrichment of waters. At its worst this causes unsightly growths of microscopic plants (algae, ibid).
NRA Classification	A classification of river water quality designed to be used as a measure of absolute quality and to monitor change. It is defined by sets of Quality Standards for key determinands.
Invertebrates	Animals which lack a vertebral column. A group of animals used for Biological Classification (ibid).
List I	Dangerous Substances (ibid) which are particularly hazardous and in need of special controls. Standards are set by the European Commission.
List II	Dangerous Substances (ibid) which are less hazardous than List I (ibid) and which are controlled by water quality standards defined by individual Member States (ibid).
Macroinvertebrates	Invertebrate (ibid) animals of sufficient size to be retained in a net with a specified mesh. A class of animals used for Biological Classification (ibid).
NWC Class	A summary of the quality of river water based largely on the measured chemical quality. Used to report on river quality from 1980 to 1990. Originally devised through the former National Water Council.
90-percentile	A level of water quality, usually a concentration, which is exceeded for 10-percent of the time.
90-percentile Standard	A level of water quality, usually a concentration, which must be achieved for at least 90-percent of the time.
Non-parametric	A calculation which requires no assumption about the data. In this report as in the use of a Non-parametric method to calculate percentiles (ibid).
Number of Taxa	A summary statistic to describe the results of monitoring rivers for the presence of benthic macroinvertebrates (ibid) (*** check ***).*** check ***
Nutrient	A chemical essential for life. If present in excess nutrients can produce the effects of eutrophication (ibid).

Parametric	A calculation which makes an assumption about the data. In this report as in the use of a Parametric method to calculate percentiles (ibid).
Percentile	In this report, a level of water quality, usually a concentration, which is exceeded for a set percentage of the time. Hence: 90-percentile (ibid).
Quality Objective	The statement or category of water quality that a body of water should match, usually in order to be satisfactory for use as a fishery or water supply etc.
Quality Standard	A level of a substance or any calculated value of a measure of water quality which must be bettered. The pairing of a specific concentration or level of a substance with a summary statistic like a percentile (ibid) or a maximum.
RIVPACS	An acronym for the River Invertebrate Prediction and Classification System. A mathematical model used to predict the invertebrate life in a river under pristine conditions. Used to calculate the Ecological Quality Index (ibid).
Salmonid Fish	Game fish, e.g. trout and salmon.
Statistically significant	A description of a conclusion which has been reached after making proper allowance for the effects of random chance.
Statutory Water Quality Objective (SWQO)	A Quality Objective given a statutory basis by Regulations made under the Water Resources Act 1991.
Taxa; Taxon	A related group of animals are said to be in the same Family or of the same Taxa. Hence Number of Taxa (ibid) is used as a summary statistic to describe the results of the biological monitoring rivers for benthic macroinvertebrates (ibid). Hence also, ASPT, the Average Score per Taxon (ibid)
Use	Attributes of a river like a fishery or a water supply.
Use-related Objective	An aim to achieve a particular Use(ibid).
Use-related Standards	Water quality standards needed to protect a Use (ibid).
Water Quality Objective:	A Use or target for a Controlled Water, which the NRA will aim to maintain or secure, e.g. a coarse fishery.

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