

APPENDIX 3.2
RIVER ECOSYSTEM
(RE) CLASSIFICATION SYSTEM

THE RIVER ECOSYSTEM CLASSIFICATION SYSTEM

In order to assess the quality of the water in different river ecosystems, we have developed a river ecosystem classification system. It is the result of research and empirical evidence concerning the basic chemical requirements of a healthy river ecosystem that is able to support fish.

The classification system is set out in The Surface Waters (River Ecosystem) (Classification) Regulations 1994, SI 1994 No. 1057. It consists of eight parameters that together form a ladder of increasing quality to reflect the needs of communities of plants and animals in our rivers. The system comprises five classes in order of decreasing quality, from RE1 (the highest quality) to RE5 (the lowest quality). Table 1 sets out the water quality criteria that each class must satisfy.

Table 1 River ecosystem classification: water quality criteria¹

Class	Dissolved Oxygen % saturation	BOD (ATU) mg/l	Total Ammonia mg N/l	Un-ionised Ammonia mg N/l	pH Lower limit as 5 percentile; upper limit as 95 percentile	Hardness mg/l CaCO ₃	Dissolved Copper µg/l	Total Zinc µg/l
	10 Percentile	90 percentile	90 percentile	95 percentile			95 percentile	95 percentile
RE1	>80	2.5	0.25	0.021	6.0-9.0	≤10 >10&≤50 >50&≤100 >100	5 22 40 112	30 200 300 500
RE2	80 - 70	4.0	0.6	0.021	6.0-9.0	≤10 >10&≤50 >50&≤100 >100	5 22 40 112	30 200 300 500
RE3	70 - 60	6.0	1.3	0.021	6.0-9.0	≤10 >10&≤50 >50&≤100 >100	5 22 40 112	300 700 1000 2000
RE4	60 - 50	6.0 - 8.0	2.5	-	6.0-9.0	≤10 >10&≤50 >50&≤100 >100	5 22 40 112	300 700 1000 2000
RE5	20	15.0	9.0	-	-	-	-	-

¹ River Ecosystem Classifications criteria parameters adjusted further to communications with Robert Kenway, Environment Agency, August 2004

The river stretch

Under the system, the Agency has classified about 40,000 km of rivers and canals. These watercourses are split into about 8,000 stretches, each one of which has been given a river quality objective (RQO). In order for a stretch to be assigned an RQO, it must have:

- a river name
- a stretch name – geographical features that define the upstream and downstream boundaries of a stretch
- an upstream grid reference
- a downstream grid reference

Each river stretch is given a water quality sampling point. This point is outside any mixing zones of discharges or tributaries, and chosen to be representative of the quality of the whole stretch.

A river ecosystem class is assigned to each river stretch, forming the RQO for that stretch.

Assessing compliance

Compliance with an RQO is assessed on the basis of data gathered by the Environment Agency over complete calendar years.

Only the results from routine, predetermined sampling programmes are used. All validated results from these programmes are placed on the Water Resources Act 1991 public registers. None of these results are set aside when assessing compliance. The RQO will not have been achieved if any of the relevant determinands significantly fails to meet the requirements in the classification.

It is inevitable that the concentration of substances in some samples will be too low to be detectable. These results are quoted as "less-than" values on the public registers, and to be taken as "zero" when assessing compliance. Rarely, results will be qualified as "greater-than" values, and are to be taken as the value specified.

In order to assess compliance with the standards set for river ecosystems, which are defined as percentiles, recognised parametric statistical methods are used. First it is necessary to calculate the mean and standard deviation values for each determinand from monitoring data held on public registers.

For a set of n results, x_1, x_2, \dots, x_n , the mean, m , is given in:

$$m = \frac{1}{n} \sum_{i=1}^n x_i$$

The standard deviation, s , is given in:

$$s = \sqrt{\frac{1}{(n-1)} \sum_{i=1}^n (m - x_i)^2}$$

From these mean and standard deviation values, it is then necessary to calculate percentile values, and to do so in a way that recognises that the taking of spot samples provides only an estimate of the underlying quality of the water being sampled. Thus, the confidence limits within which the "real" quality is assumed to lie are calculated. This is necessary to establish, with a known degree of confidence, that a failure to meet the relevant standards has occurred, in order to avoid unnecessary expenditure on improvements to discharges, which are not truly justified. The level of confidence chosen for assessment of compliance with RQOs is 95 per cent. Thus, to take account of the uncertainty resulting from spot sampling, compliance assessment is based on calculation of confidence limits, rather than on a straight calculation of percentiles.

A prescribed **parametric method** is used to estimate percentiles. Percentiles are a weighted sum of the standard deviation and the mean:

$$\text{Percentile} = \text{mean} + (\text{weighting factor} * \text{standard deviation})$$

After calculating mean and standard deviation values, the procedure is slightly different for each determinand, depending upon the nature of the standard and the assumed distribution of concentration over time.

- Two **types of standard** are used in the river ecosystem classification, and the statistical methods used to assess compliance vary according to which type of standard is applicable. For standards for which an upper limit is applicable (such that it must not be exceeded, as a 90-percentile or a 95-percentile), the weighting factor used in calculating the percentile is positive. For standards for which a lower limit is applicable (such that quality must not be less than the standard, as a 5-percentile or a 10-percentile), the weighting factor used in calculating the percentile is negative.
- Two **types of distribution** are found to approximate to the observed behaviour of class-limiting determinands in rivers: a normal distribution or a log-normal distribution. (Any error introduced by the assumption of these particular distributions is small compared with the errors from chance in sampling).

For determinands for which an upper limit standard is applicable (BOD[ATU], total ammonia, un-ionised ammonia, high pH, copper and zinc), for which a 90-percentile or 95-percentile standard is therefore applicable, the lower confidence limit is used for compliance assessment.

For determinands for which a lower limit standard is applicable (dissolved oxygen and low pH), for which a 10-percentile or 5-percentile standard is therefore applicable, the upper confidence limit is used for compliance assessment.

For a **normal distribution**, the lower confidence limit for a 90- or 95- percentile is given as q_l in:

$$q_l = m + (w * s)$$

and the upper confidence limit for a 5- or 10- percentile is given as q_u in:

$$q_u = m - (w * s)$$

where, in both cases, m is the mean, s is the standard deviation, and w is the weighting factor.

For a **log-normal distribution**, the values of the mean, m , and the standard deviation, s , are converted to the values for the logarithms of the data using the **method of moments**:

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

$$M = \ln\left(\frac{m}{\sqrt{1 + s^2 / m^2}}\right)$$

M and S stand for the mean and standard deviation of the logarithms of the data.

The lower confidence limit, q , is then the exponential of $(M + (w * S))$:

$$q = e^{(M + (w * S))}$$

where, once again, w is the weighting factor.

Annex 1 provides factors for the calculation of 95 per cent confidence limits on estimates of 10-percentiles, or 90-percentiles, and 5-percentiles, or 95-percentiles, for different sampling frequencies.

Dissolved oxygen

The **oxygen saturation**, $\%sat$, is computed for each sample, using the following equation². The calculation uses the concentration of oxygen in mg/l, mgO , and the temperature, t , in degrees C:

$$\%sat = 100 * mgO / (14.16 - 0.3943 * t + 0.00771 * t^2 - 0.0000646 * t^3)$$

² This equation is provided in Truesdale, G.A. and Gameson, A.L.H. (Water Pollution Research Laboratory) (1957). "The Solubility of Oxygen in Saline Water", *Etrait du Journal du Conseil International pour l'Exploration de la Mer*. Vol. XXII. No.2.

For dissolved oxygen, a normal distribution and the upper confidence limit are used. A site will fail the RQO for dissolved oxygen if the upper confidence limit is less than the standard.

BOD[ATU]

For BOD[ATU] (the biochemical oxygen demand, analysed in the presence of allylthiourea [ATU] to suppress the uptake of oxygen by ammonia), a log-normal distribution and the lower confidence limit are used. A site will fail the RQO for BOD[ATU] if the lower confidence limit exceeds the standard.

Total ammonia

For total ammonia, a log-normal distribution and the lower confidence limit are used. A site will fail the RQO for total ammonia if the lower confidence limit exceeds the standard.

Un-ionised ammonia

The concentration of **un-ionised ammonia**, *UnAmm*, is computed for each sample, using the following equation³. The calculation uses the concentration of total ammonia, *TotAmm*, the temperature, *t*, in degrees C, and the pH:

$$UnAmm = TotAmm / (1.0 + 10.0^{(10.055 - (0.0324 * t) - pH)})$$

In this equation, values of pH that exceed 8.0 are set equal to 8.0. This is done to take account of the observed toxicity of un-ionised ammonia in rivers of high pH.

For un-ionised ammonia, a log-normal distribution and the lower confidence limit are used. A site will fail the RQO for un-ionised ammonia if the lower confidence limit exceeds the standard.

Copper and zinc

For dissolved copper and total zinc, a log-normal distribution and the lower confidence limit are used. A site will fail the RQO for these determinands if the lower confidence limit exceeds the appropriate standard.

However, the concentration of either or both of these metals may be found to be consistently 20 per cent, or less, of the value specified as the class-limiting standard, and therefore unlikely to cause a breach of standard. In such

³ This equation is provided in *Water Research* (1973). Vol. 7. pp.1011–22. “Water quality criteria for European freshwater fish – Report on ammonia and inland fisheries”.

a case, for each affected metal, samples need to be analysed only infrequently to ensure that the metal remains at a low concentration. In these circumstances, the methods of calculation specified above do not apply.

Hardness

Samples are analysed for hardness every time they are analysed for zinc and/or copper. If hardness remains within one banding for all samples, this hardness band is used for the purpose of assessing compliance with metal standards. However, if hardness data gathered over one, two or three years spans more than one band, the average hardness will be used to assign a hardness band for the purpose of assessing compliance with metal standards.

pH range

The upper and lower limits of the pH range are treated as 95-percentile and 5-percentile respectively. A normal distribution is used. A site will fail the RQO for pH if the upper confidence limit calculated for the 5-percentile is less than the 5-percentile standard, or if the lower confidence limit calculated for the 95-percentile exceeds the 95-percentile standard.

Comparison with other assessment schemes

Some of these statistical methods differ from those generally used to assess compliance with existing EC directives. The reason for using different methods for assessing compliance with RQOs is that the methods in directives take no account of the random errors introduced by spot sampling. The methods used to assess compliance with RQOs make allowance for this error by assessing the statistical significance of compliance or failure in a way that makes maximum use of the information obtained from monitoring. This controls the risk of wasting resources on improvements to discharges into compliant sites, which might be declared wrongly to have failed because of the effect of chance in sampling. Such differences in method may lead occasionally to differences in compliance, at any given site, assessed against the requirements of a directive and against the same or similar requirements for the RQO. These will be sites at which the failure is not statistically significant.

Annex 1 Weighting factors for the calculation of confidence limits for the purpose of RQO compliance assessment

The weighting factors used to calculate 95 per cent confidence limits are shifted T-test numbers⁴. For convenience, the weighting factors for calculating confidence limits for up to 72 analytical results are listed below.

No. samples	10 or 90-%iles	5 or 95-%iles	No. samples	10 or 90-%iles	5 or 95-%iles
4	0.4428	0.7434	39	0.9655	1.2928
5	0.5177	0.8179	40	0.9691	1.2967
6	0.5737	0.8748	41	0.9725	1.3005
7	0.6180	0.9204	42	0.9758	1.3041
8	0.6541	0.9581	43	0.9790	1.3077
9	0.6845	0.9900	44	0.9821	1.3111
10	0.7105	1.0174	45	0.9851	1.3144
11	0.7330	1.0413	46	0.9881	1.3176
12	0.7529	1.0625	47	0.9909	1.3207
13	0.7706	1.0815	48	0.9936	1.3237
14	0.7866	1.0985	49	0.9963	1.3267
15	0.8011	1.1140	50	0.9989	1.3295
16	0.8143	1.1282	51	1.0014	1.3323
17	0.8264	1.1412	52	1.0038	1.3350
18	0.8375	1.1532	53	1.0062	1.3376
19	0.8477	1.1643	54	1.0085	1.3402
20	0.8573	1.1747	55	1.0108	1.3427
21	0.8662	1.1843	56	1.0130	1.3451
22	0.8745	1.1934	57	1.0151	1.3475
23	0.8824	1.2019	58	1.0172	1.3498
24	0.8897	1.2099	59	1.0192	1.3521
25	0.8967	1.2175	60	1.0212	1.3543
26	0.9033	1.2247	61	1.0232	1.3564
27	0.9095	1.2315	62	1.0251	1.3585
28	0.9154	1.2379	63	1.0269	1.3606
29	0.9210	1.2441	64	1.0288	1.3626

⁴ These weighting factors can be calculated from Pearson, E.S. and Hartley, H.O. (1972). *Biometrika Tables for Statisticians*. Vol. II. Cambridge University Press.

30	0.9264	1.2499	65	1.0305	1.3646
31	0.9315	1.2555	66	1.0323	1.3665
32	0.9364	1.2609	67	1.0340	1.3684
33	0.9411	1.2660	68	1.0356	1.3702
34	0.9456	1.2709	69	1.0373	1.3720
35	0.9499	1.2756	70	1.0389	1.3738
36	0.9540	1.2802	71	1.0404	1.3755
37	0.9580	1.2846	72	1.0420	1.3772
38	0.9618	1.2888			