NRA ANGLIAN 160

23

NRA

AMP2

National Rivers Authority
Anglian Region

AMP(2) / EFFLUENT QUALITY

NRA GUIDANCE NOTE

FOR

PREPARATION WORK FOR AMP(2)

<u>CONTENTS</u>

These Guidance Notes have been prepared following consultation with WSA and incorporate the recommendations of the UWWTD Implementation Group.

1 GENERAL GUIDANCE NOTE FOR PREPARATORY WORK FOR AMP2

1.1 INTRODUCTION

1.1.1 This guidance note has been prepared in discussion with WSA, but represents current NRA policy in respect of discharges and their future consent standards.

The guidance note will provide a pragmatic framework against which NRA Regions and WSCs can plan future needs.

1.1.2 Consistent application of these guidelines is required, but exceptionally alternative approaches will be acceptable provided that these satisfy environmental cost benefit criteria.

1.1.3 The Guidelines will therefore provide a 'level playing field' for the Companies against which their investment needs can be planned, and a benchmark against which the costs of any future changes in required performance will be assessed.

1.1.4 Works to meet current EC and somestic statutory obligations **must** be given first priority. There after in priority sequence, AMP2 should include those works:

i. agreed in the production of AMP1 and already reflected in price limits (K);

ii. required to meet new statutory, EC, and domestic obligations;

iii. necessary to maintain the environmental water quality standards at least equivalent to that measured by the 1990 river quality survey, and where justified reverse recent deteriorations; and

iv. required for targeted improvements over the above.

When implementing 1.1.4 it is not intended that river quality is restored beyond that required by the RQO, or that the RQO is achieved in advance of the date agreed with the WSC.

1.1.5 Finally, within each of the above criteria, those locations yielding most environment benefit should feature high on the list. For EC Directives, priority should be allocated in relation to the timescale in each Directive.

1.1.6 Application of these priorities will generate priority lists for investment which will then form the basis of discussion with OFWAT. This document deals separately with the following categories of Water Services Company discharges:

Inland -	Sewage Works; Intermittent Sewerage Discharges;
Tidal -	Continuous Discharges; Intermittent Sewerage Discharges.

1.1.7 The approach outlined will give a priority list for each category. It is recognised that WSC, local political, or public relations issues may cause this to be modified.

1.1.8 These lists will be assimilated together under the headings in 1.1.4 above to give a single priority order.

Points of disagreement between NRA Regions and Water Services Companies should be recorded.

However, a number of general policy assumptions apply to all these categories and are listed below.

1.2 GENERAL ASSUMPTIONS

1.2.1 The rate of progress and shape of SWQOs and any associated change to classification schemes is so uncertain that, at present, they should be omitted from discussions and costings for AMP2. It can be assumed that as a minimum they will reflect EC requirements, existing (non-statutory) RQOs and the need to reverse recent deteriorations in water quality. Nevertheless, it should be noted that references to the 1990 Survey NWC Classifications will also be taken to apply to the Classes to which they will be assigned in the General Quality Assessment Scheme, which will be applied retrospectively to the 1990 data. The NRA is unlikely to be carrying out any further national surveys based on the NWC scheme. (The General Quality Assessment Scheme is not an element of the statutory WQO Scheme).

1.2.2 This document identifies present good practice. This should normally be applied only to sites where investment is required for the reasons in 1.1.4. When investment would not be required as a result of consent changes, these assumptions should not be applied.

1.2.3 Control of non-sanitary determinands, eg, colour or pesticides, will normally be achieved by trade effluent control. However, potentially problematic WSC discharges should be identified in this review and action plans formulated taking into account the practical difficulties of control. As a minimum the relevant EQS will need to be achieved. It should be noted that the NRA has a duty in relation to the EC Dangerous Substances Directives to reduce inputs of toxic substances, and regular reviews of consent limits will be necessary.

1.2.4 For some locations, a small additional expenditure may yield significant environmental gains (eg achieve the non-statutory RQO). Such opportunistic locations should be identified.

1.2.5 However, it should not be assumed that all the environmental needs of a location will be achieved by a single tranche of investment, and phased programmes with staged consents may also need to be identified.

1.2.6 The NRA realises that much of the information relating specifically to the interests of individual Water Service Companies is commercially sensitive and as such the site specific information will be treated as confidential. This, however, does not apply to any information provided as part of individual consent applications.

1.2.7 In areas where sewerage or sewage treatment facilities are causing significant environmental problems, development will normally be opposed by the NRA until appropriate improvements have been made, unless improvements are scheduled for completion within two years or over a longer period as agreed between the NRA and the Company.

1.2.8 Nothing in these Guidelines should be construed in any way as affecting the NRA's statutory duties and powers with respect to water quality and pollution control.

AMP2 ASSUMPTIONS 1992: INLAND SEWAGE WORKS

2.1 INTRODUCTION

2.1.1 There are a number of basic assumption to be made when developing guidelines and identifying priorities for the AMP2 review. Works to meet current EC and domestic statutory obligations must be given first priority. Thereafter in priority sequence, AMP2 should include:

i. works agreed in the production of AMP1 and already reflected in price limits (K);

ii. works required to meet statutory, EC, and domestic obligations;

iii. works necessary to maintain the environmental water quality standards at least equivalent to those measured by the 1990 River Quality Survey, and where justified reverse recent deteriorations; and

iv. works required for targeted improvements over the above.

2.2 CRITERIA

2.2.1 For rivers, the principal criterion which will be generally observed is that of no deterioration in quality as defined in 2.3 below. This is an important part of NRA policy on consents for discharges.

2.2.2 In the absence of specific environmental needs, the quality standards to be adopted will be those of the UWWTD, see Annex 1.

In the absence of specific environmental needs, the standards for suspended solids and/or COD should not determine the scale of treatment provision. For COD it may be acceptable to use the percentage removal as set out in the UWWTD.

For UWWTD requirements it is expected that under normal circumstances the directive limits of 125 mg/l COD will apply, but in exceptional circumstances when this is difficult to achieve, due to trade effluents input, the percentage removal approach may be adopted.

2.2.3 The normal requirement for flow passing to full treatment is 3PG+I+3E. Variations may be permitted following environmental cost benefit; for example, a lower flow may be permitted from very large sewerage systems or indeed a higher flow to full treatment without storm tankage for small systems. Under these circumstances due regard should be paid to the criteria for storm sewage overflows in the Guidance Note on Intermittent Sewerage Discharges.

2.2.4 Storm treatment should normally be given by provision of storm tank capacity of 68 l/hd or two hours at 3PG+I+3E or by a process giving equivalent performance. Consents for tank discharges will normally be descriptive and require that any overflow should only contain storm sewage and that the storm tanks should be properly maintained. There may be exceptions to this where the content of trade effluent requires that authorisation is necessary under EC Directives other than UWWTD (which may include solids limits). Storm tank contents should be returned to the flow for full treatment as soon as practicable after cessation of a storm.

2.2.5 The overflow of unsettled storm sewage at the works is considered in the same manner as intermittent discharges and is dealt with on the same basis as combined sewage overflows. (Section 4).

2.3 DEFINITION OF NO DETERIORATION

2.3.1 The NRA will not permit significant within-class deterioration nor a reduction in river class below that of the existing, non-statutory, RQO. In calculating consents for sites requiring investment, the following criteria should be used:

i. no planned worsening in the existing NWC Class;

ii. no planned change of more than 10% in the mean and 95%ile concentrations of key determinands in the receiving water as recorded in 1990 unless there is insignificant environmental changes as a consequence;

iii. no increase over the consented load in 1989, or the consented load in RQO- related consents issued since 1989, unless there is insignificant environmental change as a consequence.

Item (i) will be actioned by having an existing NWC target Class which is no worse than that reported in 1990, and account must be taken of the need to reverse recent deteriorations.

2.3.2 For new and existing effluents from sewage works serving population equivalents of less than 2,000, appropriate treatement as agreed by the UWWTD Implementation Group should be provided. The precise form of treatment will be dependent upon the size of the discharge relative to the receiving water and will be, typically, one of the following: trickling filter, activated sludge plant, rotating biological contactor, reed bed or equivalent alternative system .where such a discharge has the potential to cause environmental problems then numeric standards will apply, otherwise a descriptive consent will be appropriate. In all cases the discharger will be asked to have documented maintenance procedures. In these cases the provisions in paras 1.2.2 and 2.2.2 both apply. A positive review of existing consents to incorporate this requirement is not necessary.

2.3.3 For population equivalents of 250 and below, which contain no trade effluent, a descriptive consent will normally be appropriate unless there is significant environmental impact or the discharge occurs close to an area with public access.

2.3.4 In some cases, especially for rivers, the assessment will sometimes lead to consents which are strict in terms of the capabilities of the technology available to treat wastewaters. Where this happens for existing discharges, the NRA will provide special justification for imposing standards which are stricter than the equivalent of the following, for sewage effluents, the values of which are based on 12 month 95%iles monitored by spot samples:

- Suspended Solids 10 mg/l; or
- BOD 10 mg/l; or
- Ammonia 5 mg/l as N.

2.3.5 In setting consents, each effluent will be allowed the full dilution capacity of the water at the point of discharge for the purpose of mass-balance calculations, taking account of the strictest of all the limits defined by the existing non-statutory RQO and by No Deterioration as defined in paragraph 2.3. This will require rapid and efficient dilution in the first phases of mixing.

2.3.6 Dispersion and dilution will usually replenish the capacity of the water to receive more discharges. For degradable pollutants, natural purification will also restore capacity.

2.3.7 If the capacity of a water is fully committed at a site, the NRA will refuse applications for new discharge pending a review of the consents of the existing discharges. Any such locations should be identified on the priority list.

2.4 ASSUMPTION AND PRIORITIES FOR ACHIEVING RQOS

2.4.1 Effluent standards will be set to achieve the existing downstream non-statutory RQO using procedures set out in Annex 2.

2.4.2 Whilst the NRA would expect to make progress to eliminate or reduce the length of Class 4 rivers, and upgrade Class 3, as defined by the NWC system, the overall approach should be to concentrate efforts on those cases where significant improvements in quality are needed and can be justified.

2.4.3 Where the upstream river water quality complies with the existing, non-statutory RQO, the measured upstream quality should be used in the consent calculation. If there is little or no information, or where the upstream quality does not meet the RQO, then the mid-point of the objective class should be used.

2.4.4 Where a watercourse is not classified, maintenance of an existing downstream objective may be used to determine the consent. However, a pragmatic approach is required for discharges to drainage ditches.

2.4.5 The immediate downstream target quality for a river being upgraded should generally be no greater than the lower limit of the upper quartile of the existing NWC class, ie, 8 mg/l BOD for Class 2. However, in places where self purification is high, the poorer boundary of the class may be an appropriate target. In all cases the current river classification scheme should be used until the General Quality Assessment scheme is introduced.

2.4.6 The requirements for flows to full treatment and for storm treatment are outlined in 2.2.3 and 2.2.4 above.

2.4.7 Where ammonia standards are necessary to meet existing non-statutory RQO requirements, they should be applied on a seasonal basis taking account of available dilution. The normal period of application should be May to October. The impact of reducing temperature on the efficiency of nitrification should be considered in setting winter ammonia consents. In such cases the absolute value set in the consent should not lead to additional investment unless there is a demonstrable environmental reason.

2.4.8 Any relaxation for construction purposes should be for the minimum period necessary to carry out the work and should have regard to protection of downstream quality.

2.5 STANDARDS TIGHTER THAN THOSE REQUIRED FOR EXISTING RQOS

2.5.1 It is not considered necessary at present to make allowance for any proposals for the designation of inland bathing waters under the relevant EC Directive.

2.5.2 The designation of sensitive and less sensitive areas under the EC UWWTD will be those agreed by the Secretary of State and designated by him for action. Until these are defined, the existing notifications by DoE through the UWWTD Implementation group will apply. Identification and designation of Vulnerable Zones under the EC Nitrate Directive will be decided early in 1993. It should be assumed that additional treatment will be required to remove phosphorus from the sewage effluents of plants serving >10,000 pe and discharging to sensitive areas designated as eutrophic. Nitrogen may have to be removed from the effluents if the eutrophic sensitive area is designated because it exceeds the 50 mg/l NO_3 limit and is abstracted for drinking water purposes.

2.5.3 No account should be taken of the EC Ecological Quality of Surface Waters Directive (which is yet to be published) in this exercise.

2.6 EXCHANGE OF INFORMATION BETWEEN NRA AND WSA

2.6.1 To enable satisfactory AMP2 planning, it will be necessary for WSCs and their appropriate NRA Region to exchange information so that priorities and consents for the periods 1995-2000 and 2000-2005 can be costed.

The attached spreadsheet outline indicates the whole of the information which is likely to be required for the exercise. However, it is likely that only a subset of this information need be shared in order that the exercise can be carried out effectively. It is at the discretion of each WSC and the appropriate NRA Region to decide the extent of data sharing necessary.

2.6.2 The spreadsheet illustrates the environmentally relevant information which will enable the Regional NRA to discuss these in a structured way with the WSCs in order to generate a priority list of investment needs. The final priority lists will need to take into account other operational needs of the WSCs. It would be advantageous if the majority of this information can be agreed with the relevant WSC, in particular to:

- identify environmental problems associated with each discharge;
- identify relative priorities for investment; and
- plan consenting and construction programmes to comply with a timescale reflecting overall priorities.

The information is grouped into different subsets which reflect different stages in an improvement scheme directed at solving problems in a phased manner, that is:

- information relating to the existing discharges; and
- information on the proposed discharge which is to be constructed in each subsequent stage of the improvement scheme.

This information should be treated as confidential and must not be released outside the Regional NRA staff and the individual WSC.

INLAND SEWAGE WORKS SPREADSHEET

Consents Planning Database: Summary of Information Requirements

1. Basic Information

Works Name
Receiving Watercourse Name
Operating District
NRA Area
Works NGR

2. Summary Indicators of Future Requirements

Aim To provide a summary indication of triggers for consent changes.

COMP	Performance Requirement v Existing Consent: Improve, Maintain or No Action.
DEV/GRO	Increased consented flow needed to meet Development and Growth requirements.
UWWTD1	Must meet minimum standards of UWWTD.
UWWTD2	Nutrient removal under UWWTD.
RQO	Needs further improvement to meet existing non-statutory RQO.
NRA	NRA Priority.

3. River Quality Requirements

U/S RQC
U/S RQO
D/S RQC
D/S RQO
Date for RQO Achievement (When approved)
EC Fish Directive Classification
Sensitive Area - N removal required
Sensitive Area - P removal required

4. Consent Details

4.1 Current

DWF
Maximum Flow to Full Treatment (MFFT)
Maximum Flow to Partial Treatment (MFPT)
Temporary Schedule DWF

Quality Limits (95%ile and Upper Tier if applicable):

BOD (ATU)
Suspended Solids
Ammonia

Metals (May only flag presence)
Pesticides (May only flag presence)

4.2 Projected Consents at 31 March 1994 (AMP1)

As 3.1 above but taking account of current investment programme.

5. Projected Flow Data

Design Horizon Date
Population (P) - P_1 & P_2 (Separate/combined)
Per Capita Consumption (G)
Infiltration (I)
Trade Effluent (E)

DWF
MFFT
MFPT

6. Projected Long Term Consents (AMP2 and Beyond)

Indicative long term consents based on projected flows in Section 5 and relevant EC and UK quality requirements.

7. Detailed Consent Timetable

Required dates for:

Agreement of consent details;
Submission of consent application;
Issue of consent;
Consent effective.

NB: Driven by date required for consent to be effective. Needs to take account of design, tender and construction timescales.

8. Performance Data

Summary of works performance v current and projected consents.

9. Cost Data

Aim: To allow assessment of scheme costs in relation to environmental consents.

AMP2 ASSUMPTIONS 1992: CONTINUOUS DISCHARGES TO TIDAL WATERS

CRITERIA FOR ESTABLISHING RELATIVE NRA PRIORITIES FOR IMPROVING DISCHARGES TO TIDAL WATERS

3.1 INTRODUCTION

3.1.1 These guidelines are intended to ensure that the appropriate priority is given to environmental improvements to discharges to tidal waters and that they are made at a reasonable cost through AMP2. Work to meet current EC and domestic statutory obligations **must** be given first priority. Thereafter, in priority sequence, AMP2 should include:

i. works agreed in the production of AMP1 and already reflected in price limits (K);

ii. works required to meet new statutory, EC, and domestic obligations;

iii. works necessary to maintain the environmental water quality standards at least equivalent to those measured by the 1990 River Quality Survey, and, where justified, reverse recent deteriorations; and

iv. works required for targeted improvements over the above.

3.1.2 The programme for improving the quality of discharges to tidal waters will depend largely on the existing timetable for implementation of the EC Bathing Water Directive agreed between the Water Companies and DoE and on that for the EC UWWTD. Investment work required to ensure compliance with the UWWTD must be completed by the end of 1998, 2000 or 2005, depending on discharge size and receiving water type, as set out in Annex 1. Discharges should be prioritised for improvement work in order to meet deadlines in the Government's Bathing Water programme and in the UWWTD. The needs of the new EC Shellfish Health Directive, if any, will also need to be addressed.

3.1.3 Criteria which should be taken into account when planning the improvement programme within the context of the UWWTD are listed in Table 3.1. The criteria are, in general, not necessarily presented in order of priority. It is recognised that because of the tight timescale required by the UWWTD, the scope to reflect other priorities will be limited.

3.1.4 Except where specified, the criteria apply to all discharges (continuous/intermittent). Discharges should be ranked by impact, hence an inland STW which adversely affects tidal water quality (eg bathing waters) would be priority rated alongside such discharges which pass direct to tidal waters.

3.1.5 Where appropriate, a phased approach to capital works and consenting issues should be adopted when tackling complex problems, so as to provide early environmental improvements pending completion of a scheme. Investment has been initially directed towards achieving EC Bathing Water Directive compliance, with further investment continuing in stages if subsequent investigation indicates that problems remain.

3.1.6 Where a number of different objectives have been identified at a given site, schemes designed to deal with the priority objectives (eg meeting the UWWT Directive) should take account of the need to meet the further objectives at some future time.

3.1.7 These guidelines are to be used to provide a framework for assessing investment priorities for discharges to tidal waters. They should be applied in the light of common sense and local knowledge. In cases where use of the guidelines gives rise to apparent priorities which are at odds with perceived needs, discussion at an appropriate level between the NRA and WSC should take place to agree on subsequent action.

3.2 GUIDE NOTES TO PRIORITIES

3.2.1 No specific reference is made to the NWC classification system for estuaries as this is subjectively applied and is therefore inappropriate. Nevertheless, the criteria listed are consistent with the elimination of NWC class C/D estuaries as a high priority.

3.2.2 The UWWTD requirement for "appropriate treatment" for discharges with population equivalents smaller than those specified in the UWWTD must be in accordance with the recommendations of the UWWTD Implementation Group. The timetable for introducing appropriate treatment must reflect this obligation and require improvements to be made by the end of 2005 (UWWTD timescale).

3.2.3 No reference is made to the introduction of SWQO's for tidal waters as no DoE guidance is available at present.

3.2.4 Investment to comply with the UWWTD may be phased from 1995 to meet the Directive timetable and beyond. This requires clear definition in AMP2.

3.2.5 The opportunity exists to balance benefits and costs by allowing lower ranked priorities to receive attention in advance of higher ranked priorities, where the population and/or area affected serves to justify this. Similarly, development pressure in embargoed areas may justify 'priority jumping'.

3.2.6 The extent of amenity use should be considered when assessing priorities. Where it is to be taken into account, amenity use should be significant and not merely sporadic or infrequent.

3.2.7 It has been assumed that guidance from DoE/MAFF will be forthcoming on target classes for the EC Shellfish Health Directive, and Regulations are expected in early 1993. Current NRA powers on public health matters are listed in Sections 92-97 of the Water Resources Act 1991 in relation to the prevention of pollution. In the absence of DoE/MAFF guidance on implementation, no provision can be made for this Directive in AMP2.

3.2.8 The guidelines given will be used to identify priorities for investment to solve the specific problems listed as resulting from discharge impact. There is no presumption that a WSC investment scheme, designed to remedy the specific problems identified, should also address other quality issues relating to the receiving water, although the WSC may choose to extend the scope of a scheme to do so at its own discretion. Thus, if a scheme is in AMP2 because of a need to address a high priority problem, it will not be intended to address an associated low priority problem unless this is specifically agreed. The low priority problem would be tackled later in the investment programme at an appropriate time - possibly as part of a phased overall scheme.

TABLE 3.1: CRITERIA TABLE FOR PRIORITIES WITHIN THE UWWTD INVESTMENT PROGRAMME

The overall improvement timetable will be dictated by the EC Bathing Waters Directive and by the EC UWWTD requirements. The following criteria will determine priorities within the UWWTD timetable.

	CRITERIA	COMMENTS
1	Non-compliance with EC Shellfish Waters Directive	This relates to existing designated Shell-fisheries under the Directive. It is not intended to anticipate any future designations at this stage.
2	Non-compliance with EC Dangerous Substances Directives	Sewage discharges causing non-compliance will normally be improved through trade effluent controls. However, in certain instances relocation and/or additional treatment may be necessary.
3	Nationally significant inputs of Red List Substances (North Sea Conference Declaration)	Most sewage discharges to be improved through trade effluent controls. However, improved sewage treatment may be appropriate at certain locations. Flow monitoring facilities required in order to measure load.
4	Impedes the free passage of migratory fish	In most instances, improvement will be required to estuarine ammonia/oxygen levels.
5	Contaminated designated shell fisheries resulting in C/D Classification under Shellfish Health Directive.	Shellfisheries to be designated and classified by 1 January 1993, renewable annually. Sewage discharges may require high level of treatment and/or relocation. This will need revision following DoE/MAFF advice.
6	Continuous crude discharge exposed at MLWS and publicly accessible	To be eliminated.
7	Directly degrades the conservation value of a designated conservation area	Sites affected to be agreed with English Nature or Countryside Council for Wales.
8	Crude discharge, causes objectional levels of debris to contaminate popular general amenity beaches and/or waters	Sewage debris is the principal concern, together with international obligations concerning plastic materials.
9	Adversely affects amenity value	Discharges give rise to smell/visual problems. Discharge fails to meet initial dilution criteria as specified in NRA policy and agreed following consultation with WSCs (see 3.4.1.1)
10	Adversely affects water contact sports	Includes general amenity waters.
11	Adversely affects local ecology	
12	Adversely affects fishery interests	Includes shellfisheries
13	UWWTD compliance only	No environmental impact. Investment necessary only to meet UWWTD requirements with regard to the relevant population thresholds. "Appropriate treatment" will be required for smaller discharges. Includes elimination of crude discharges and provision of appropriate screening at continuous discharges.

3.3 COASTAL WATERS

In considering investment needs beyond the basic requirements of the EC Bathing Waters and UWWT Directives, appropriate uses from the following list should be safeguarded:

- commercial harvesting of shellfish;
- the amenity of beaches and other areas;
- water contact recreation;
- general biology; and
- special conservation needs.

3.3.1 Standards to Apply

Where the uses in 3.3 lead to investment the following standards will be used.

3.3.1.1 Bathing (EC designated waters) - the imperative standards for faecal coliforms and total coliforms as specified in the EC Bathing Waters Directive will apply. There should be negligible evidence of the presence of persistent synthetic material attributable to discharges.

3.3.1.2 Effluent treatment standards specified in the EC UWWTD will apply as minimum standards to discharges from population equivalents as specified in the Directive.

3.3.1.3 On general amenity beaches where water contact recreation is recognised, the necessary treatment should be installed to ensure that the general public does not come into contact with gross sewage solids. Where it is considered that a serious public health risk exists, then improvements in accord with NRA policy (issued to the Forum on the Environmental Impact of Disinfected Sewage Effluents, 15 January 1992) should be costed. There should be negligible evidence of the presence of persistent synthetic material attributable to discharges.

3.3.1.4 Commercial harvesting of shellfish - further advice on requirements to be sought from DoE/MAFF.

3.3.1.5 General Biology - EQSs specified in the EC Dangerous Substances Directive will apply.

3.3.1.6 Special Conservation Needs - site specific standards will apply.

3.3.2 Levels of Treatment for Continuous Discharges

3.3.2.1 The UWWTD levels of treatment will apply to discharges to coastal waters in accord with the recommendations of the UWWTD Implementation Group.

They will apply to discharges serving populations equivalent to those stipulated in the Directive. The designation of sensitive and less sensitive areas will be those agreed by the Secretary of State. Until these are defined, the existing notifications by DoE through the UWWT Directive Implementation Group will apply.

3.3.2.2 In areas designated as **less sensitive** under the terms of the UWWTD a minimum dilution of 200:1 at one nautical mile from the discharge point will apply.

3.3.2.3 For all qualifying discharges under the EC Bathing Water and UWWT Directives, an **initial dilution** will be determined by the NRA following consultation with WSC. Guidance on the standards required for initial dilution will be issued separately.

3.3.2.4 Where a phased approach to meeting treatment standards is necessary, appropriate consents will be issued by the NRA to reflect the phasing of construction schemes.

3.3.2.5 Where WSCs choose to consider disinfection as a treatment option the NRA will notify them of the requirements. The NRA will undertake regular reviews of policy on disinfection techniques in the light of ongoing studies.

3.3.2.6 Disinfection should provide a level of environmental protection which is no less than that provided by conventional methods of treatment and disposal. Disinfection will be required over the whole year except where there are no clear benefits in maintaining the dosing/application systems continuously.

3.3.2.7 It should be assumed that additional treatment to reduce nitrate **but not phosphate** will be required for discharges to coastal waters which are designated as sensitive waters.

3.3.2.8 The following level of treatment will generally apply to discharges serving population equivalents smaller than those specified in the UWWTD but with flows greater than 10 m^3/d.

i. Preliminary treatment (ie, screening and removal of persistent material) will be required in cases where basic amenity and general ecosystem conservation are the only recognised receiving water uses.

ii. Primary treatment or higher will be required in cases where significant water contact based recreation is a recognised receiving water use. Exceptionally, secondary treatment or higher will be required in cases where the discharge is made **within** the area of significant recreational use.

iii. Secondary treatment will be required in cases where the discharge enters an area of poor water exchange (eg, harbours and marinas). Identification of such an area is to be agreed by the WSC and the NRA Region prior to finalisation of AMP2.

iv. For smaller flows, nuisance should be avoided.

v. The position of the outfall may affect the relative sophistication of treatment required.

3.3.3 Investigative Studies

3.3.3.1 WSCs will pay the full costs of all reasonable investigative studies in support of consent applications associated with, and appropriate to, the scale of the investment schemes. Pre - and post - construction studies funded by the WSCs may be required. (Guidance will be provided to NRA Regions as soon as possible and this will be communicated to WSCs).

3.3.3.2 Regular disinfection efficacy testing will be required for discharges which are subject to disinfection. Consents for such discharges will be reviewed on the basis of the results of such monitoring.

3.3.3.3 WSCs will consult the NRA to determine whether studies to assess the likely impact of the discharge are required. Where appropriate, WSCs may be required to undertake site specific monitoring to establish the environmental impact of construction work. The WSC should consult NRA Regions on each proposed scheme to establish whether such studies will be necessary.

3.3.3.4 Subsequent to the initial designation by DoE, WSCs may be required to fund any additional studies as required by the EC UWWTD to identify other less sensitive areas. There will be no requirement for such studies if a discharge is subject to secondary or a higher level of treatment.

3.4 ESTUARIES

3.4.1 Definition

3.4.1.1 Estuary boundaries will be those defined for the purposes of the UWWTD. For the purposes of defining initial dilution it may be permissible to amend this definition in line with NRA policy and following consultation with WSC.

3.4.2 Standards to Apply

In considering investment needs beyond the basic requirements of the Bathing Waters and UWWT Directives, the appropriate uses from the following list should be safeguarded:

- commercial harvesting of shellfish;
- the amenity of beaches and other areas;
- water contact recreation;
- general biology;
- special conservation needs; and
- migratory salmonid fishery.

3.4.2.1 The UWWTD levels of treatment will apply to discharges to estuarine waters and accord with the recommendations of the UWWTD Implementation Group. They will apply to discharges serving populations equivalent to those stipulated in the Directive. Designation of sensitive and less sensitive areas is currently being considered by the Secretary of State. Each NRA Region should use the current provisional lists of such areas.

3.4.2.2 Subsequent to the initial designation by DoE, WSCs may be required to fund any additional studies as required by the UWWTD to identify other less sensitive ares. There will be no requirement for such studies if a discharge is subject to secondary or a higher level of treatment.

3.4.2.3 Standards applied to protect the above uses will be the same as those identified for the protection of legitimate uses in coastal waters with the following extra standards applying where the migratory salmonid fishery use is recognised:

Dissolved Oxygen	5 mg/l 95%ile, 3 mg/l absolute minimum;
Ammonia	0.021 mg/l annual average unionised ammonia as N, 0.25 mg/l unionised ammonia as N, not to be exceeded.

For design purposes it should be assumed that a maximum average concentration of 0.021 mg/l unionised ammonia, as N, will apply over a tidal cycle during critical periods of the year. Where there are scientifically derived standards available, specifically applicable to individual estuaries, these may be used as alternatives.

3.4.3 Levels of Treatment

3.4.3.1 Treatment levels specified in the UWWTD will apply to discharges serving populations equivalent to those stipulated in the Directive.

3.4.3.2 Subject to the recommendations of the UWWTD Implementation Group, the normal requirement for flow to full treatment is 3PG+I+3E, but a lower flow may be used for very large sewerage systems or indeed a higher flow to full treatment (without storm tankage) for small systems.

3.4.3.3 Requirements for screening and initial dilution will be determined following consultation with WSC. It may be permissible to modify dilution requirements in cases where the required standards may not be achievable, eg, in cases where there are moveable channels, shipping movements, or extensive mud flats.

3.4.3.4 The effluent treatment standards specified in the UWWTD will apply as a minimum to those discharges serving populations equivalent to those specified in the Directive.

3.4.3.5 Discharges to estuaries serving equivalent populations smaller than those specified in the UWWTD will be subject to appropriate treatment (see 3.3.2.8) or, in the case of small discharges (less than 10 m^3/d) to avoid nuisance.

3.4.3.6 It should be assumed that additional treatment to reduce nitrate levels **but not phosphate** will be required for discharges in estuaries which are designated sensitive areas.

3.4.4 Investigative Studies

3.4.4.1 Policy and assumptions relating to investigative studies for discharges to coastal waters will also apply to discharges to estuaries. WSCs will pay the full costs of all reasonable investigative studies associated with investment schemes if they are solely responsible for pollutant inputs into the receiving water. If other point source discharges also contribute to critical pollutant loadings, costs of investigative studies will be shared between the WSCs, NRA and where appropriate, other dischargers. If inputs unattributable to other dischargers are present, the NRA may pay the relevant portion of study costs.

3.5 TIDAL DISCHARGE REGULATION SPREADSHEET

3.5.1 To enable satisfactory AMP2 planning, it will be necessary for WSCs and their appropriate NRA Region to exchange information so that priorities and consents for the periods 1995-2000 and 2000-2005 can be costed.

The attached spreadsheet outline indicates the whole of the information which is likely to be required for the exercise. However, it is likely that only a subset of this information need be shared in order that the exercise can be carried out effectively. It is at the discretion of each WSC and the appropriate NRA Region to decide the extent of data sharing necessary.

3.5.2 The spreadsheet illustrates the environmentally relevant information which will enable the Regional NRA to discuss these in a structured way with the WSCs in order to generate a priority list of investment needs. The final priority lists will need to take into account other operational needs of the WSCs. It would be advantageous if the majority of this information can be agreed with the relevant WSC, in particular to:

- identify environmental problems associated with each discharge;
- identify relative priorities for investment; and
- plan consenting and construction programmes to comply with a timescale reflecting overall priorities.

The information is grouped into different subsets which reflect different stages in an improvement scheme directed at solving problems in a phased manner, that is:

- information relating to the existing discharges; and
- information on the proposed discharge which is to be constructed in each subsequent stage of the improvement scheme.

This information should be treated as confidential and must not be released outside the Regional NRA staff and the individual WSC.

CONTINUOUS TIDAL DISCHARGES SPREADSHEET

A EXISTING DISCHARGE

1. Basic Information

Consent Reference
Discharge Name
Discharge National Grid Reference
Receiving Water Name
Receiving Type (Coastal/Estuary/River)
Receiving Water UWWT Designation (Less Sensitive/Normal/Sensitive)

2. Discharge Status

Treatment level (Crude/Preliminary/Secondary/Tertiary/CSO)
Minimum available dilution at 3 DWF (actual)
Population equivalent: Design
Population equivalent: Actual
Current consent:
- DWF
- MFFT
- MFPT
- Percentage of time assumed for MFPT
- BOD
- SS
- NH3
- Others
- Spill frequency
- Storage

3. Investment Priorities

Primary Investment Needs
- EC Bathing Water Directive
- UWWT Directive

Other Priorities
- EC Shellfish Waters Directive
- EC Dangerous Substances Directive
- Red List Input
- Impact on Migratory Fish
- Shellfishery Contamination
- Designated Conservation Area
- Crude Discharge (Impact scored 0-3)
- Amenity Impact
- Water Contact Impact
- Ecological Impact
- Fishery Impact
- Premature CSO discharge

Development Pressure (High/Medium/Low)
Affected Population (High/Medium/Low)
UWWT Directive compliance only

Receiving Water

EC Bathing Water
Non EC Bathing Water
EC Shellfish water or EC Shellfisheries classification water
Other Shellfishery
Migratory Fishery
Recreation
Special Conservation
Basic Amenity
General Ecosystem

B PHASE 1 DISCHARGE (AMP2) (when the investment is made over a number of phases)

1. Basic Information

Consent Reference
Discharge Name
Discharge National Grid Reference
Receiving Water Name
Receiving Water Type (Coastal/Estuary/River)
Receiving Water UWWTD Designation (Less Sensitive/Normal/Sensitive)

2. Discharge Requirements

Phase 1 objective (Problems to be addressed - from section A3)
Treatment level (Preliminary/Primary/Secondary/Tertiary/CSO)
Minimum available dilution at 2DWF (actual)
Screen size (mm)
Population equivalent
Phase 1 consent:

DWF
MFFT
MFPT
Percentage of time assumed for MFPT
BOD
SS
NH3
Others
Spill frequency
Storage

3. Timetable (Target dates as at 31.5.95, actual dates may change depending on external factors such as constraints on funding)

Consent agreed
Consent application
Consent issued
On site
Commissioned
Completed
Consent effective

C PHASE 2 DISCHARGE etc

Same information requirements as for Phase 1 discharge

4 FRAMEWORK FOR CONSENTING INTERMITTENT DISCHARGES

4.1 INTRODUCTION

4.1.1 Article 3 of the EC UWWTD requires member states to ensure that agglomerations with a population equivalent of 2000 or more are provided with collecting systems. It further requires that the collecting systems satisfy the requirements of Annex I(A) of the Directive. This states that the design, construction and maintenance of collecting systems shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding, among other things, the limitation of pollution of receiving waters due to storm water overflows.

4.1.2 The Directive acknowledges the impracticability of constructing collecting systems and treatment works such as to treat all waste water during situations such as unusually heavy rainfall. It therefore places responsibility on member states, to decide on measures to limit pollution from storm water overflows, and suggests that these measures could be based on:

- dilution rates; or
- the capacity of the collecting system in relation to dry weather flow; or
- a certain number of overflows per year.

This paper represents a position agreed by the Department of the Environment, the Scottish Office Environment Department, Department of the Environment (Northern Ireland), OFWAT, NRA, WSA and COSLA for implementing the storm overflow elements of the Directive in the UK and is intended to assist WSCs in determining their investment programmes in this area. This framework paper is supported by two, more detailed Guidance Notes on consenting intermittent sewage discharges, including:

- combined sewer overflows (CSOs);
- pumping station emergency overflows; and
- storm overflows at sewage treatment works.

to freshwaters, estuaries and coastal waters. A separate paper produced for the DoE implementation Group for the UWWTD is concerned with engineering design standards.

4.1.3 This paper and the supporting Guidance Notes set down in general terms, the requirements which are to be met to ensure compliance with the Directive. In certain circumstances, for the purpose of protecting the water environment, the regulatory agencies may require more stringent standards to be met than those specified in the notes. In view of the local nature of such circumstances it is not appropriate to cover these in this paper or in the notes. Rather they are for consideration at the local level between the regulatory agencies and the sewerage undertaker.

4.1.4 In total there are about 25,000 such intermittent discharges and it is estimated that about two thirds are satisfactory. The Guidance Notes set out criteria for consenting those overflows that are unsatisfactory; that is, the factors to be taken into account, and the methodology and the model consent conditions to be adopted. The intention is to ensure that a common approach is used by regulatory agencies and that dischargers, mainly WSCs, are treated in a similar manner. The requirements are set out with the objective of trying to adopt as simple an approach as possible consistent with meeting the Directive's requirements but a more complex approach will be required where particular circumstances warrant it. It is also not intended to be totally prescriptive; there must always be the opportunity for flexibility to take account of cost and environmental benefits and to meet specific local requirements.

4.1.5 With so many discharges to consider, a fundamental question arises concerning the implementation of the guidelines. The framework proposed starts from the assumption that the regulators will not, in the short to medium term, wish to direct resources to reviewing all intermittent discharge consents just because some of the present consents do not conform with one that would be issued according to the Guidance Notes. This is consistent with DoE advice on the interpretation of the UWWTD. Regulatory authorities and WSCs will examine priorities and timescales jointly.

4.1.6 The subsequent sections set out a framework within which effort will be focused on the discharges that are unsatisfactory and for which the WSCs need to spend money to alleviate these problems over agreed timescales. Over a longer period of time most overflows will be brought within the framework as flows increase or engineering works are required for other purposes. The trigger will be either that an overflow has become unsatisfactory (see below) or is predicted to be close to becoming so because of changes that are known to be taking place. The use of interim measures as a staged improvement would be acceptable.

4.1.7 Progress on implementation has to meet the requirements of the UWWTD. This requires that the design, construction and maintenance of collecting systems is undertaken in accordance with best technical knowledge not entailing excessive costs, notably regarding:

volume and characteristics of urban waste water;
prevention of leaks; and
limitation of pollution of receiving waters due to storm water overflows.

The Guidance Notes contribute to the definition of "best technical knowledge", as mentioned in Annex IA of the Directive particularly in the context of limitation of pollution.

4.1.8 The Directive requires the necessary laws, regulations and administrative procedures to be in place by 30 June 1993. All agglomerations with a population equivalent of 2000 or more should have collecting systems unless there are special circumstances. Where there are sensitive areas and a population equivalent of over 10,000, the requisite collecting systems must be in place by 31 December 1998. Requisite collecting systems must be provided for a population equivalent of over 15,000 in areas not identified as sensitive by 31 December 2000. All other implementations are required by 31 December 2005.

4.1.9 A tighter UK timescale has been established for achieving bathing water quality standards as required by the EC Bathing Water Directive. Sewerage and sewage treatment schemes are now targeted for completion in virtually all cases by 31 December 1995.

4.2 PUMPING STATION EMERGENCY OVERFLOWS RECOGNISED AS A CONSTITUENT PART OF THE COLLECTING SYSTEM

4.2.1 Sewage pumping stations are recognised as part of the collection system and normally possess emergency overflows which are designed to protect the pumping station or other property from flooding in the event of pumping station failure. The cause is usually mechanical or electrical failure and if flooding did occur the station could be sufficiently damaged to be taken out of service for days or weeks rather than a few hours. Because these overflows may operate in dry weather and often discharge to relatively small watercourses, their environmental impact can be larger than CSOs. The emphasis in pumping station consents is to ensure that there are adequate arrangements for a quick response to minimise pollution from emergency overflows. These will depend on local circumstances. For example, the waste water undertaker may wish to provide storage, standby equipment or access for tankers. Where the undertaker chooses to provide storage within the sewage system or at the pumping station, for normal situations 1-2 hours storage at 3PG + I + 3E would be acceptable. For pumping stations causing or likely to cause problems, consents will be reviewed and, where necessary, enhanced levels of protection or improved back up arrangements will be specified over agreed timescales.

4.3 UNSETTLED STORM OVERFLOWS AT SEWAGE TREATMENT WORKS

4.3.1 These will be considered in the same manner as CSOs. They are usually reviewed when the consent for the treatment works is reviewed and it is not considered necessary to have a general review. Clearly, if one is unsatisfactory according to the criteria in Section 4.4.1 it should be treated as any other CSO but this may need to be tied in with a review of the consent for the whole works.

4.4 DEFINITION OF UNSATISFACTORY COMBINED SEWER OVERFLOWS

4.4.1 The following criteria are to be used in deciding which CSOs are unsatisfactory and, therefore, subject to consent review to drive improvements.

(i) causes significant visual or aesthetic impact due to solids, fungus and has a history of justified public complaint;

(ii) causes or makes a significant contribution to a deterioration in river chemical or biological class;

(iii) causes or makes a significant contribution to a failure to comply with Bathing Water Quality Standards for identified bathing waters;

(iv) operates in dry weather conditions;

(v) operates in breach of consent conditions provided that they are still appropriate; and/or

(vi) causes a breach of water quality standards (EQS) and other EC Directives.

It is also appropriate to pay due regard to the presence of designated shellfish waters in the vicinity of a CSO. However, it should be noted that, when the EC Directive on Production and Marketing of Shellfish was implemented on 1 January 1993, the faecal coliforms standard given in the Annex to the EC Directive on the Quality of Shellfish Waters reverted from an "imperative" to a "guide" value. (Further guidance will be issued in due course).

4.4.2 The criteria given in 4.4.1 are largely objective although some subjectivity may apply in the case of (i). It is not considered productive at this stage to refine these definitions further. The NRA is conducting research into the quantification of some of these issues. Some discretion must be left for local interpretation of the significance and contribution of an overflow to a particular problem, taking account of the costs and benefits.

4.5 CONSENTING OF SATISFACTORY COMBINED SEWER OVERFLOWS

4.5.1 Only consents for unsatisfactory existing CSOs as defined in Section 4.1 need to be reviewed. Those that are satisfactory will therefore meet the requirements of the UWWTD and consequently there is no need to review their consents to incorporate the requirements of the appropriate Guidance Note. A consent may exist which is adequate or a discharge may require a consent because it is currently unconsented or is one of the scheduled consents issued by schedule at the time of water privatisation in England and Wales.

4.5.2 If a new consent is required for an existing satisfactory CSO that is not subjectto change, it need only specify current conditions. These should include a statement of carry-forward flow where this information is available and should include any other facilities such as screens etc, currently installed.

4.5.3 Revised consents will clearly be required for existing satisfactory CSOs if their status changes ie, they become unsatisfactory. This is covered in Section 6.

4.6 CONSENTING OF UNSATISFACTORY, NEW AND ALTERED COMBINED SEWER OVERFLOWS TO RIVERS

4.6.1 Consents will be reviewed or determined as a priority in the following cases:

(i) storm overflows that are unsatisfactory according to the criteria set out in 4.4.1;

(ii) new storm overflows;

(iii) storm overflows that are identified, as a result of drainage area studies, as potentially becoming unsatisfactory in the near future; and

(iv) storm overflows that will potentially change their operating characteristics due to changes in the sewerage network (eg, consolidating CSOs).

4.6.2 If the performance is unsatisfactory due to only one of the criteria in 4.4.1 then the review should take the form of tightening only the performance of the failing criterion, subject to the proposed solution not adversely affecting other criteria. For example, if the CSO operates in dry weather conditions but does not cause any problem in respect of the other criteria, the review need only look at the carry-forward flow or the provision of storage. If the problem is only one of solids deposition, then a solids condition may be all that is required.

4.6.3 However, if the CSO is failing on two or three criteria, or is a new or radically altered discharge, then the consent review should take account of the relevant factors.

4.7 PROCEDURE FOR REVIEWING CSOs TO FRESHWATERS

4.7.1 The Guidance Note for discharges to freshwaters sets out the criteria which determine how a consent is to be reviewed and the model conditions that are to be incorporated. Three different approaches have been suggested in relation to the significance of the discharge. These require different levels of sophistication to determine the quality criteria (reflected in the carry forward flow). Indicative criteria for impact assessment are set out in Table 4.1. For the less significant discharges it is proposed to use minimum data methods (eg, Formula A or QUALSOC). However, there may be circumstances where, for very high dilutions, less demanding requirements than Formula A may be acceptable. For the highly significant discharges the adoption of sewer hydraulic analysis and water quality modelling with a model such as Mike 11 require significant data collection and modelling facilities, but are only envisaged to be required in relatively few circumstances. In between these two extremes there is a discretionary band where sewer hydraulic models, together with simpler water quality models (eg, QUALSOC, QUALSIM, CARP), may be utilised and which have less demanding data requirements.

4.7.2 When models are used to determine consent conditions, it is important to use some form of sensitivity analysis to check the impact of any assumptions made on the final outcome. The outcome must also be reviewed if the costs of potential solutions are excessive in the context of benefits gained.

4.7.3 The procedures and models referred to in the document for use with highly significant cases will be expanded on in the Urban Pollution Management Manual, which will be published by the Foundation for Water Research in 1994.

TABLE 4.1 INDICATIVE IMPACT ASSESSMENT CRITERIA FOR SETTING CONSENTS FOR CSOs TO FRESHWATERS

LOW SIGNIFICANCE
Minimum Data Methods eg, Formula A, or possibly QUALSOC Method Dilution >8:1 (foul DWF @ 5%ile low river flows) No interaction with other discharges This approach is likely to be adequate in most cases.
MEDIUM SIGNIFICANCE
Simple Models (eg, SDD Method, QUALSOC, QUALSIM, CARP + sewer hydraulic model such as WALLRUS) Dilution <8:1 No interaction or limited interaction with other discharges >2000 population equivalent Cyprinid fishery This approach is only likely to be required if all of these criteria apply.
HIGH SIGNIFICANCE
Complex Models (eg, sewer hydraulic models such as MOSQITO and river quality models such as MIKE II - to be overtaken by UPM Procedures) Dilution <2:1 Interaction with other discharges >10,000 population equivalent Cyprinid or salmonid fishery This approach is only likely to be required if all of these criteria apply.

4.8 DISCHARGES INTO COASTAL WATERS AND ESTUARIES

4.8.1 Intermittent discharges to coastal waters and estuaries impact on three different types of water: EC identified bathing waters, which have a special status, EC designated Shellfish Waters, and other waters (used for activities such as recreation, contact sports, shellfish rearing and basic amenity). The most stringent conditions apply to those identified as EC Bathing Waters.

4.8.2 Priorities for action will again be focused on the unsatisfactory discharges. In the context of coastal waters and estuaries, similar criteria can be used as for freshwaters (Section 4.4.1) except that (ii) is inappropriate. A suggested approach is summarised in Table 4.2.

4.8.3 The guidance note on discharges to coastal waters sets out criteria for the regulatory authority to determine consents based on the number of acceptable spills per bathing season to each of these waters. If it can be demonstrated that a scheme can be designed with no more than a 1.8% risk of failure of the Bathing Water Directive, specifically due to CSOs, then alternatives may be considered. These are on the assumption that the discharge is directly to the water concerned and located below MLWS (soffit level).

4.8.4 If the discharger decides to take the discharge outside of the identified bathing water or to use alternative means and can demonstrate satisfactorily that the alternatives will enable the EC Bathing Water Directive standards to be met, then this will be acceptable.

TABLE 4.2 INDICATIVE IMPACT ASSESSMENT CRITERIA FOR SETTING CONSENTS INTO COASTAL WATERS AND ESTUARIES

LOW SIGNIFICANCE
Minimum data methods (eg, Formula A) Estuarial and coastal waters not containing EC identified bathing waters and/or shellfish waters
MEDIUM SIGNIFICANCE
Simple Models (sewer hydraulic model with frequency assessment of overflow spill) Population equivalent 2,000 - 10,000 Affects identified bathing waters and/or shellfish waters This approach is only likely to be required if both criteria apply.
HIGH SIGNIFICANCE
Complex models (sewer hydraulic model with frequency assessment of overflow spill and an option for coastal dispersion model and impact assessment) Population equivalent > 10,000 Affects identified bathing waters and/or shellfish waters This approach is only likely to be required if both criteria apply.

5 CONSENTING INTERMITTENT SEWAGE DISCHARGES INTO FRESHWATERS

UWWT GUIDANCE NOTES

5.1 INTRODUCTION

This document sets out the basis of guidance for issuing consents for intermittent sewage discharges into freshwaters. The discharges covered include combined sewer overflows (CSOs), and storm tank discharges, at sewage treatment works and pumping stations.

This Guidance Note supplements the document "Framework for Consenting Intermittent Discharges", and should be read in conjunction with it. The Note sets out the basis of policy, agreed by the Department of the Environment, The Welsh Office, The Scottish Office Environment Department, and the Department of the Environment (Northern Ireland), for issuing consents for combined sewer overflows (CSOs) discharging to freshwaters. Although the standards set down in this Note are considered to meet the provisions of the EC UWWTD, it is acknowledged that there will be certain circumstances where, for the purpose of protection of the water environment, more stringent standards may be necessary. Due regard will be given to cost and environmental benefits in such cases.

5.2 DEFINITIONS

5.2.1 **DWF - Dry Weather Flow** For design purposes calculated by the equation:

DWF = PG + I + E where:
P = Population served;
G = Water consumption per head per day;
I = Infiltration allowance; and
E = Trade Effluent flow to sewer as applicable.

5.2.2 **Formula A** A CSO setting as defined in the Report of the Technical Committee on Storm Overflows and the Disposal of Storm Sewage (1970)[1]. The Formula should be amended, as described in the Report, for any separate areas within the sewer catchment. Where storage is provided at a CSO, and in very large sewerage systems where significant smoothing of flows occurs, this will be taken into account in defining the performance equivalent to "Formula A" without storage.

The standard "Formula A" is DWF + 1350P + E, where flows are expressed in litres/day, but minor local variations have been developed and are acceptable provided they are fully documented.

5.2.3 SCOTTISH DEVELOPMENT DEPARTMENT METHOD (SDD Method)

An extension of the Formula A methodology using storage to limit pollution from CSOs according to the dilution capacity of the receiving stream, using the following definitions.

Available Dilution	Percentage Spill	Overflow Arrangement
8	100	Formula A
4	50	Formula A + 40 l/hd storage
2	25	Formula A + 80 l/hd storage
1	12	Formula A + 120 l/hd storage

5.2.4 WALLRUS

A hydraulic sewer model developed by Hydraulics Research, Wallingford.

5.2.5 CARP

A comparative procedure developed by WRc for assessing CSO improvements required to achieve a good quality coarse fishery in a river.

5.2.6 QUALSOC

A simple mass balance procedure for setting spill rates of CSOs.

5.2.7 QUALSIM

A statistical procedure which is a development of QUALSOC for assessing CSO improvements.

5.2.8 MIKE 11

A suite of models developed by the Danish Hydraulics Institute with a component sponsored by the FWR Urban Pollution Management Programme. It is intended for assessing the impact of intermittent discharges using a dynamic approach.

5.3 APPLICATION OF GUIDANCE

This guidance applies to all new and unsatisfactory intermittent sewage discharges to any fresh waters in the UK.

5.4 NORMAL REQUIREMENTS

The following requirements will normally apply.

5.4.1 Retained Flow

The sewerage system must be designed so that the discharges are not made until the incoming flow exceeds that calculated from "Formula A" as defined in 5.2.2. For existing satisfactory situations less demanding requirements may be acceptable when dilution is high.

5.4.2 Aesthetic Control

The discharge should not create any visual or aesthetic impact caused by solids, paper, plastic or fungus as demonstrated by a history of justified public complaints or concern.

5.4.3 Water Quality Impact

The discharge should not cause, or significantly contribute to, a deterioration in water quality standards.

5.4.4 Consent Conditions

* Consents issued must include necessary conditions such as overflow location, type, weir setting, storage requirements etc, and aesthetic performance standards as appropriate to the receiving water uses.

* It will not be necessary to apply numeric, chemical and bacteriological quality conditions in the consent.

* The requirements may in certain circumstances be for the provision of a storm event/duration monitor, the results from which would normally be presented in the form of an annual report from the discharger.

5.4.5 Appraisal Techniques

Three different methodologies are currently available to set CSO Consent Conditions and these are defined as follows:

1. **discharge control** based upon Formula A or QUALSOC (Section 5.6);

2. **impact assessment** using simple procedures and models eg, SDD, QUALSOC, CARP (Section 5.7); and

3. **dynamic river quality approach** using intermittent water quality standards, with complex sewerage and environmental modelling techniques eg, WALLRUS, MIKE 11 (Section 5.8). This is being developed by the UPM procedures.

The choice of which procedure should be used should be determined by the impact of the discharge.

5.5 ASSESSING THE IMPACT OF A DISCHARGE

The requirements for the engineering and environmental assessment needed to specify design standards will be directly related to the size and potential significance of the scheme.

In defining significance the following Table 5.1 provides guidance for selection of a particular methodology.

TABLE 5.1

INDICATIVE IMPACT ASSESSMENT CRITERIA FOR SETTING CONSENTS FOR CSOs TO FRESHWATERS

LOW SIGNIFICANCE
Discharge Control Methods eg, Formula A[1], or in some cases QUALSOC Dilution > 8:1 (foul DWF @ 5%ile low river flows) No interaction with other discharges This approach is likely to be adequate in most cases.
MEDIUM SIGNIFICANCE
Impact assessment using Simple Models (eg, SDD method, QUALSOC, QUALSIM, CARP + sewer hydraulic model such as WALLRUS) Dilution <8:1 No interaction or limited interaction with other discharges >2000 population equivalent Cyprinid fishery This approach is only likely to be required if all of these criteria apply.
HIGH SIGNIFICANCE
Complex Models (eg, sewer hydraulic models such as MOSQITO and river quality models such as MIKE II - to be overtaken by UPM Procedures) Dilution <2:1 Interaction with other discharges >10,000 population equivalent Cyprinid or salmonid fishery This approach is only likely to be required if all of these criteria apply.

5.6 DISCHARGE CONTROL METHODS

Where the impact of discharges is of low significance, then assessment can be less sensitive and the use of Formula A as defined in 5.2.2 and its modifications are the most appropriate.

Storm treatment should normally be given by provision of storm tank capacity of 68 l/hd or 2 hours storage at 3PG+I+3E or by a process giving equivalent performances. Storm tank contents should be returned to the ongoing flow for full treatment as soon as practicable after cessation of a storm.

5.6.1 Formula A[1]

This traditional approach to combined sewer overflows has been based upon hydraulic criteria to assess the size of the downstream sewer, and takes little account of the assimilative capacity of the receiving watercourse.

5.6.2 The Scottish Development Department Report 1977[7]

This provides guidelines for deciding upon the amount of storage to be incorporated within a combined sewer overflow structure. The level of storage is dependent upon the dilution factor (ie stream 95% exceedance flow/sewer DWF). This method does not predict the receiving water impact. It only attempts to reduce the impact of the discharge to a lower level, which may or may not be acceptable, depending on the river quality objectives of that river.

Design guidelines are given in the SDD report for overflow settings and tank capacities where dilution in the receiving stream is limited.

5.6.3 QUALSOC[5, 8, 9]

QUALSOC uses a simple mass balance technique that enables the effects of varying the weir setting (spill rate) on the water quality downstream of the overflow to be estimated. In its current form the water quality parameter used is the 5-day BOD value and the overflow impact is assessed against the Maximum Admissible Concentration value (MAC) in the downstream river appropriate to the river classification.

5.7 THE IMPACT ASSESSMENT APPROACH

In the circumstances where impact assessments utilising sewer hydraulic models are required, as set out in Table 5.1. The data requirements for the building of a full dynamic sewerage and river model are considerable and in many circumstances cannot be justified for the size or impact of the scheme. A first approach is to consider the use of the following procedures.

5.7.1 QUALSIM

A statistical procedure which is a development of QUALSOC for assessing CSO improvements.

STANDARDS

Table 5.2 sets out standards which may be used as guidance in the QUALSOC - QUALSIM procedures for the achievement of appropriate class for supporting a viable fishery.

TABLE 5.2

GUIDANCE STANDARDS FOR QUALSOC/QUALSIM MODELS

River Class	BOD LIMIT		
	95%ile mg/l	99%ile mg/l	MAC mg/l
1B	5	9	12
2	9	16	20

5.7.2 CARP[5, 6]

CARP is an interim procedure for spill load estimates. This is used to calculate acceptable spill loads to individual river reaches by comparing the pattern of load input with a river reach of similar characteristics which receives significant spills but still attains its desired quality objectives.

5.8 THE DYNAMIC APPROACH USING RIVER QUALITY STANDARDS FOR INTERMITTENT DISCHARGES

5.8.1 In rivers seriously affected by intermittent polluting discharges from large urban conurbations, intermittent river quality standards are required. The aim is to provide standards which ensure the long term survival of fish and other biological life. Intermittent standards for water quality have been proposed by WRc and standards have been developed based on the following parameters:

(a) return period of an event, eg, occurs once a year;
(b) the duration of the event, eg, lasts two hours; and
(c) the magnitude of the pollution eg, river concentrations should not exceed 3 mg/l of ammonia.

By setting appropriate standards to protect aquatic life, the impact of sewerage schemes can be assessed and design conditions set for an acceptable discharge.

These standards should be suitable for use in the application of the complementary dynamic river discharges model MIKE 11.

5.8.2 Return Period

The standards have been developed to achieve a satisfactory quality in the river for events with a 1 year return period. A rolling 5 year period could be the minimum practical time period over which to judge performance. Appropriate return periods for design purposes will be available through the UPM procedures in due course, or in the MIKE II Application Guide currently being issued.

5.8.3 Event Duration

The duration of an event and its effect on a river is difficult to model. For practical application it is recommended that a short term duration could be 6 hours; other duration periods may be considered.

5.8.4 Magnitude

From the chosen return period and event duration the limit for dissolved oxygen and ammonia can be determined from the research recommendations.

5.8.5 Standards

It is recommended that, as an interim measure, the receiving water quality standards to achieve and support a viable fishery with respect to intermittent discharges could be expressed as in Table 5.3.

Over the next two years the Urban Pollution Management Manual will be produced which will specify the methodology, suitable models and data requirements in greater detail.

These standards should be suitable for use in the application of the complementary dynamic river discharges model MIKE 11.

TABLE 5.3

Recommended Criteria for 6 Hour Return Period

Duration of Event	6 hours
Return Period	1 year
Dissolved Oxygen	$\geq$3.5 mg/l
Total Ammonia	$\leq$5.0 mg/l

5.9 AESTHETIC CONTROL

5.9.1 The major objective in controlling CSO discharges is to minimise the presence of objectionable solids and persistent materials in watercourses. This can be achieved by a number of means, for example the design of the overflow structure or the provision of screens.

5.9.2 Design

The WRc Guide to Design of Storm Overflow Structures[10] should normally be used and, as a minimum, the installation should be of a type which gives acceptable solids separation and retention (eg a properly designed high sided weir, stilling pond or vortex separator). Such structures as leaping weirs, low sided weirs and holes in a wall are unacceptable unless no adverse impact is noted from existing structures.

5.9.3 Aesthetic Control

For NEW AND EXISTING UNSATISFACTORY CSOs there will be a standard requirement that solids separation should achieve removal of a significant quantity of solids having a size greater than 6 mm in any two dimensions. Existing unsatisfactory CSOs should be treated as new CSOs, with improvements to meet the higher standards required within a defined timescale and which may be staged.

5.9.4 Storm Tank Discharges

The normal requirement is for all sewage flows up to 3PG + I + 3E to be fully treated. Flow between 3PG + I + 3E and 6PG + I + 3E or Formula A as defined in 5.2.2 should normally have tank treatment provided by storm tank capacity of 68 l/hd or two hours at 3PG + I + 3E as appropriate or by a process giving equivalent performance. Flows greater than 6PG + I + 3E should be dealt with as CSOs.

REFERENCES

In the preparation of this document the following references have been taken into account.

1. Ministry of Housing and Local Government Technical Committee on Storm Overflows, HMSO, 1970.

2. Proposed water quality criteria for the protection of aquatic life from intermittent pollution: Dissolved Oxygen, Water Research Centre, Medmenham 1990, PRS 2498-M.

3. Proposed water quality criteria for the protection of aquatic life from intermittent pollution: Ammonia, Water Research Centre, Medmenham 1991, NR 2682.

4. NRA Policy Implementation Guidance Note SC/CC/002 - Interim guidance on issuing consents for discharge (internal).

5. Interim river quality planning procedures for controlling intermittent pollution from storage sewage overflows, Water Research Centre Report ER316E.

6. Time Series Rainfall, Water Research Centre Report ER 195E.

7. Storm Sewage Separation and Disposal; Scottish Development Department, HMSO, 1977.

8. QUALSOC, Storm Sewage Overflow Policy Group October, 1988, Welsh Water Authority.

9. QUALSOC, User Manual January, 1991, Version 5, Welsh NRA.

10. A guide to the design of storm overflow structures, Water Research Centre, Report ER304E. 1988.

11. WRC/CIRIA Tech Note 132 Phase III Stormwater Overflows and Pumping Station,1991.

6. CONSENTING COMBINED SEWER OVERFLOWS (CSOs) INTO COASTAL WATERS AND ESTUARIES

UWWT GUIDANCE NOTES

6.1 INTRODUCTION

This Guidance Note supplements the document "Framework for Consenting Intermittent Discharges", and should be read in conjunction with it. The Note sets out the basis of policy, agreed by the Department of the Environment, The Welsh Office, The Scottish Office Environment Department, and the Department of the Environment (Northern Ireland), for issuing consents for combined sewer overflows (CSOs) discharging to estuarial and coastal waters. Although the standards set down in this Note are considered to meet the provisions of the EC UWWTD, it is acknowledged that there will be certain circumstances where, for the purpose of protection of the water environment, more stringent standards may be necessary and due regard will be given to cost and the environmental benefit. Control of combined sewage overflows to coastal and esturial tidal waters is needed to ensure that, where waters are identified under the provisions of the EC Bathing Water Directive, compliance with the requirements of that directive is not compromised by the adverse effect of such discharges.

The guidance recognises the need to protect other uses of coastal and esturial waters, such as recreation and amenity. With these waters there is currently no statutory requirement to be met. The regulatory authorities, however, have a duty to maintain and where necessary improve the quality of waters in the marine environment.

It is also recognised that there are distinct variations in the nature of receiving coastal and esturial waters of the UK. This guidance is therefore designed to take into account local conditions and provide a framework for issuing consents which reflect the local needs and benefits to the environment.

The need to limit the operation of tidal CSOs and provide emission control of sewage solids through the use of appropriate solids retention techniques is also described.

6.2 DEFINITIONS

6.2.1 Bathing Season

The period during which monitoring is carried out in accordance with EC Bathing Water Directive requirements. (For sewerage scheme design purposes this is May to September, inclusive, in England and Wales, and 1 June to mid September in Scotland and Northern Ireland).

6.2.2 Identified Bathing Waters

Refers to those bathing waters identified by the UK under the provisions of the EC 'Bathing Waters' Directive.

6.2.3 Other Waters

Includes those other waters used for activities such as recreation and water contact sports.

6.2.4 Soffit Level

The level of the top inner surface of the outfall pipe.

6.2.5 MLWS

The level of Mean Low Water Spring tides as given in the Admiralty Tide Tables and corrected, where necessary, for the actual location of the outfall.

6.2.6 On Average

Normally, the average over a period of not less than 10 years.

6.2.7 Spill Frequency

The number of significant spills from a CSO into the environment per bathing season or per year as appropriate. The number of spills may be based on observed spill frequency or that predicted using a verified sewer system model and long term rainfall data (See Appendix B). The size of spill which qualifies as significant will depend upon a number of factors. In general, however, for design purposes a spill greater than 50 m^3 will be significant.

6.2.8 Estuarial Waters

All waters defined as estuarial as defined under the provisions of the EC UWWTD.

6.2.9 Coastal Water

All marine waters up to the 3 nautical mile limit, excluding estuaries.

6.2.10 Formula A

As defined in Section 5.2.2. Where there is a significant influx of holiday population then the alterative of 6 x Dry Weather Flow (defined as 6PG + I (summer) + 3E) can be used.

6.2.11 DWF - Dry Weather Flow

For design purposes calculated by the equation:

DWF = PG + I + E where:
P = Population served; and
G = Water consumption per head per day.

I = Infiltration allowance; and
E = Trade effluent flow to sewer as applicable.

6.3 APPLICATION

6.3.1 This guidance applies to all new or unsatisfactory combined sewage overflows discharging to any esturial and coastal waters in the U.K.

6.3.2 No specific bacteriological Environmental Quality Standards currently exist for water other than those for identified Bathing Waters. This document therefore suggests interim target performance standards for guidance. A "Guide" value for faecal coliforms is given in the Annex of the EC Shellfish Waters Directive for designated shellfish waters.

6.3.3 The procedure for consenting storm discharges to coastal waters is outlined in the flow diagram in Appendix A.

6.4 MINIMUM REQUIREMENTS

In general, subject to specified exceptional circumstances, the following requirements will apply as a minimum.

6.4.1 Minimum Retained Flow

The sewerage system should be designed so that the CSO will not spill until the incoming flow exceeds that calculated from "Formula A" as defined in 5.2.2, and 6.2.10, or equivalent. The Formula is to be amended as described in the Report for any separate areas within the sewered catchment. Where storage is provided at a CSO and in very large sewerage systems where significant smoothing of flows occur, then this shall be taken into account in defining the performance equivalent to "Formula A" without storage.

6.4.2 Location

The outfall soffit level of all CSOs must be located below the level of low water mark of mean spring tides (MLWS) unless the following exceptional circumstances apply.

Bathing Waters

Where there are particular local extenuating circumstances which either prevent, or render it impractical to locate the outfall in accordance with the minimum requirement above, then a spill frequency standard to limit CSO operation to, on average, 1 SPILL IN EVERY 5 BATHING SEASONS should be applied and the outfall located on a case by case basis.

Other Waters

Decisions should be based on local factors, for example visibility of pipe, direct access by the public, overflow located in cliff face etc, and also the practical engineering considerations of construction and maintenance. The use of an alternative means of achieving the required standards is acceptable.

6.4.3 Consent Conditions

Consents will include such necessary conditions as overflow location, type, weir setting, storage requirements, etc to limit the operation of, and the aesthetic performance of such overflows, as appropriate to the receiving water uses.

It will not be necessary to set numeric, chemical and bacteriological quality conditions in the consent, but the requirements may, in certain circumstances, be for the provision of a storm event/duration monitor, the results of which would normally be in the form of an annual report from the discharger.

6.5 USE RELATED SPILL FREQUENCY DESIGN STANDARDS

6.5.1 Where spill frequency standards are applicable under this section, WSCs should provide full technical information, including any modelling undertaken, in order to determine the expected spill frequency performance of the CSOs. The steps to be taken in applying spill frequency standards are shown diagrammatically in Appendix A.

Where the WSCs wish to apply standards different from those given in 6.5.2 they will need to complete validated sewer hydraulic modelling and time series rainfall response estimates for the system using historic rainfall records covering the most recent period of 10 years. Shorter periods should only be accepted where such local records are not available. Guidance on recommended methods is given in Appendix B.

6.5.2 Identified Bathing Waters

The maximum number of independent storm event discharges via the combined sewer overflow(s) to identified bathing waters, or in close proximity to such waters, must not, on average, exceed the spill frequency standards of 3 SPILLS PER BATHING SEASON. This spill frequency will apply:

a) unless the CSO has not, historically, caused non-compliance of the EC Bathing Water Directive; or

b) unless the wastewater undertaker demonstrates that the scheme is designed to achieve the water quality standards of the EC Bathing Water Directive for at least 98.2% of the time.

6.5.3 Higher Protection (Lower Spill Frequency) Levels

For CSOs operating at a spill frequency of not more than 1 in 1 year a 10 mm bar screen emission performance will be acceptable.

6.5.4 EC Designated Shellfish Waters

The discharge from any new combined sewer overflows into designated Shellfish Waters should be avoided. For existing unsatisfactory overflows discharging directly to shellfish waters the undertaker should adopt a policy of improvement to minimise such spills.

6.5.5 Other Waters

There are currently no statutory provisions for these waters. As a minimum, Formula A, as specified in 5.2.2 will apply.

* If it can be demonstrated that this level of protection will produce no significant environmental benefit, then the sewered area should be treated on a case by case basis, where necessary supported by investigations and modelling exercises.

* If, because of local use requirements, a more stringent standard of protection is needed, monitoring and modelling exercises are required to assess the required discharge frequency.

6.6 IMPACT CRITERIA

Where the waste water undertaker intends to extend the outfall of the CSO some distance offshore of MLWS to achieve improved dispersion of the discharge of storm sewage, the following criterion may be adopted.

Achievement of the water quality standards of the EC Bathing Water Directive should be achieved in not less than 98.2% of the bathing season.

The impact criterion should ONLY be used in those circumstances where extensive studies, including field exercises, can be undertaken and the regulatory authority with responsibility for auditing such information provided by the sewerage undertaker can be reasonably satisfied with the validity of the assumptions made and the predictions produced. See Reference 2 for further advice on this approach, if applicable. Small volume discharges as defined in 6.2.7 may be exempted from impact criteria requirements.

6.7 CONTROL OF DISCHARGE OF SOLIDS

The control of discharge of solids is required on a year-round basis and therefore consent calculation must be based on annual data and generally based on WRc report No 9, 1991 (reference 2).

The steps to be taken in applying solids separation techniques to achieve aesthetic emission standard are shown diagrammatically in Appendix C. A method for predicting total volumes (from annual time series rainfall) for the requirements and corresponding flow limits is summarised in Appendix D.

The specified solids control applies to the volumes discharged after application of the appropriate engineering design to achieve the requirements of sections 4-6 as applicable to the receiving waters.

Any form of solids control will be considered, provided it can be demonstrated to meet the standards reasonably comparable to the polluting load removed by aperture screens, as set out below.

6.7.1 Identified Bathing Waters

For new and existing unsatisfactory CSOs, solids separation is required to achieve removal of a significant quantity of solids having a size greater than 6 mm in two dimensions.

It is not necessary for all the storm flow to comply with this condition as follows.

* Where the CSO is designed to have a spill frequency of 1 in 1 Bathing Season or less, then the discharge should not contain any significant quantity of solid matter greater than 10 mm in any two dimensions. Persistent material should be removed or returned to the ongoing flow.

* For storm flows greater than 80% of the total volume which is calculated to be spilled during a typical year, then the discharge should not contain any significant quantity of solid matter greater than that which would be retained by a 10 mm bar screen.

6.7.2 Other Waters

For new or unsatisfactory CSOs, there will be a minimum standard requirement that the discharge should not contain any significant quantity of solid matter which could be retained by a 10 mm bar screen or equivalent.

* If it can be demonstrated that this high level of protection will produce no significant environmental benefit, then the screening requirement may be relaxed subject to the agreement of the regulatory authority.

REFERENCES

In preparation of this document the following references have been taken into account.

1. Technical Committee on Storm Overflows. HMSO 1970. Ministry of Housing and Local Government (1970)

2. Overall design approach for demonstrating compliance with Bathing Water Standards. Report No. 9, WRc Report No. UC693, March 1991.

3. Thomas DK, Brown S J & Harrington SW (1989). Screening at Marine Outfall Headworks. Journal of IWEM Vol 3, No 6 December 1989.

4. Draft framework for Consenting Intermittent Discharges. NRA (1992).

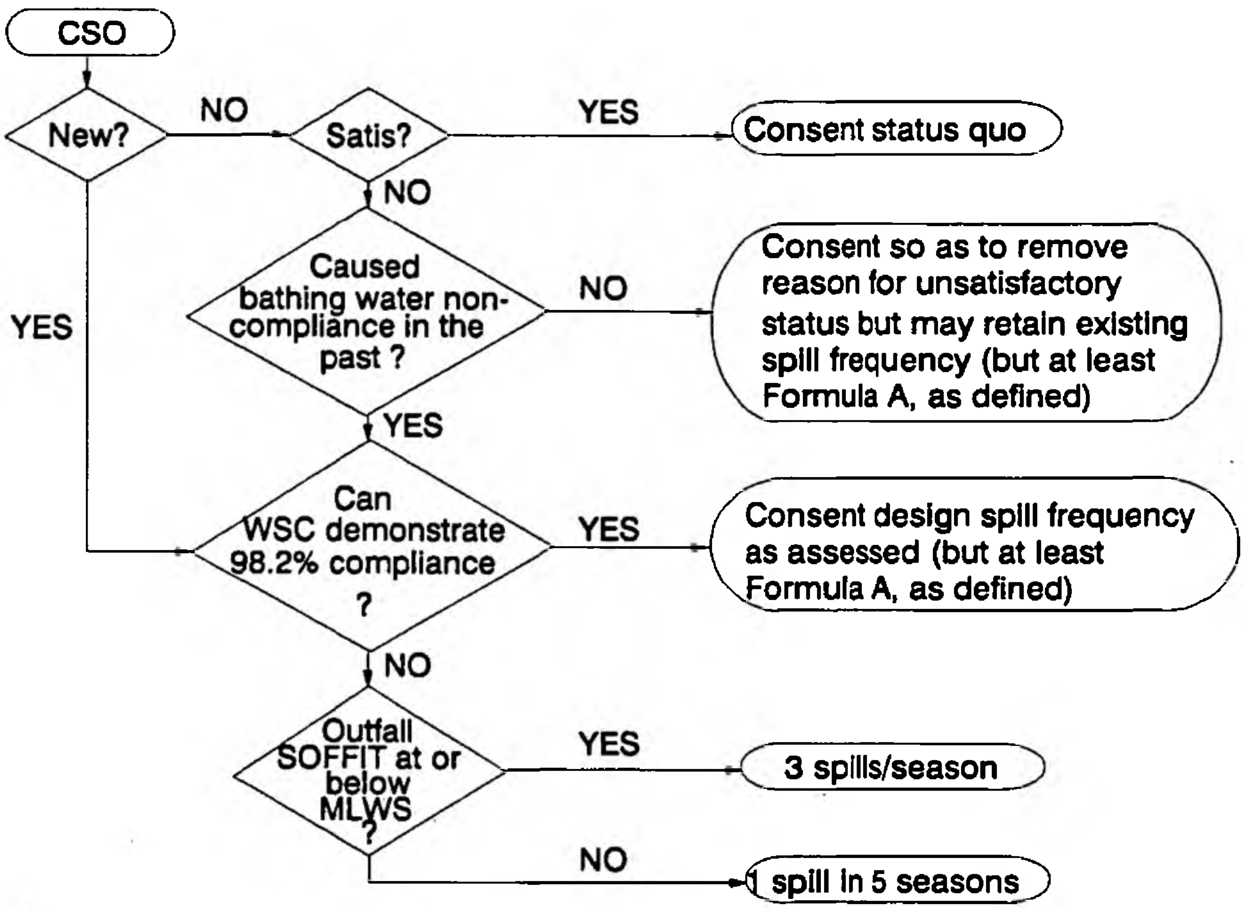
5. Consenting Combined Sewer Overflows to Tidal Waters. Wessex Water (1992).

6. Summary of Case Studies. Wessex Water (1992).

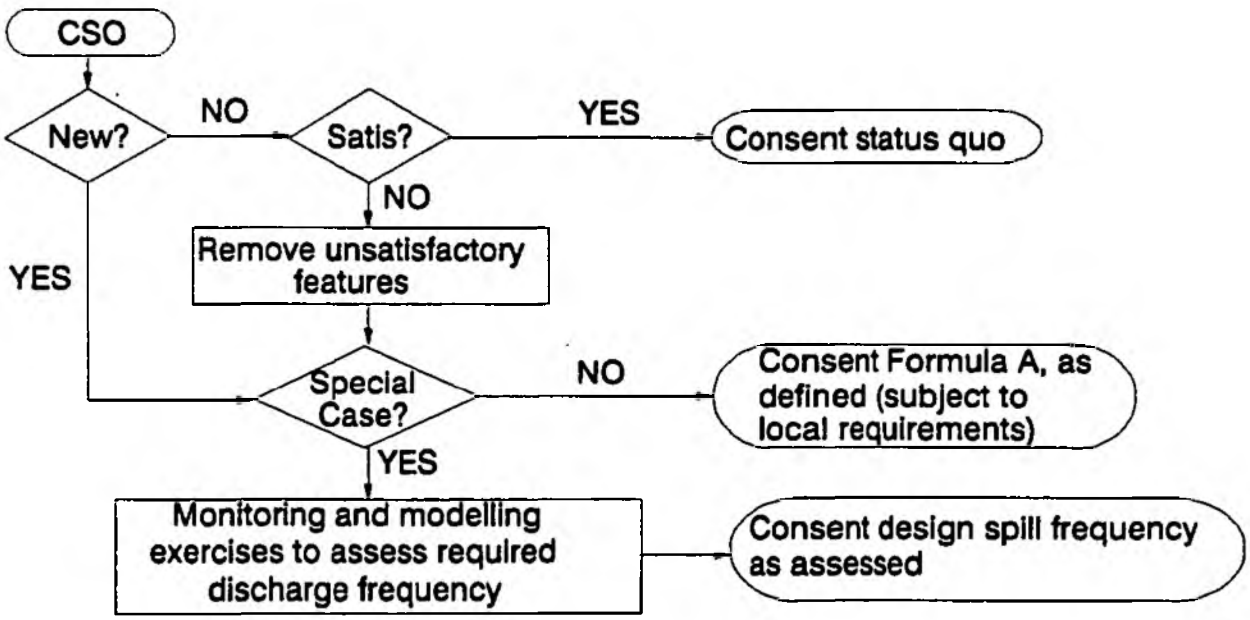
SPILL FREQUENCY STANDARDS - COASTAL WATERS & ESTUARIES

EC Designated Bathing Waters

Spill Frequency



Other Waters



APPENDIX B

RESPONSE OF SEWERAGE SYSTEMS TO TIME SERIES RAINFALL USING SEWER HYDRAULIC MODELLING

In this guidance note reference is made to the need for a validated sewer hydraulic model and the analysis of time series rainfall events during the bathing season. This analysis is required to ensure confidence that an appropriate assessment of risk has been made.

The Coastal Sewerage Research Group (CSRG) have investigated methods of analyzing the data for time series rainfall as obtained from the Meteorological Office to produce confident predictions of spill frequencies over long time periods.

These are:

Method 1 Gross characteristics of historical storms only. Urban Catchment Wetness Index (UCWI) fixed. No sequencing of events.

Method 2 Historical storms used directly with hydraulic models making maximum use of hourly information. UCWI values calculated for each storm event.

Recommended Development of SMARTS (Storm Water Management Analysis with Rainfall Time Series) Model. UCWI values calculated for each storm event. Full sequencing of events over rainfall time series.

All methods require that a prior validated sewer hydraulic model of the catchment is produced (eg WASSP/WALLRUS).

The recommended method allows full sequencing of events, that is the storm tank contents at the end of one storm are taken as the start condition for the next event. It is dependent on the use of the SMARTS model.

This method also allows investigation of pumping regimes to control discharges within a defined tidal window if this provides operational advantages. The results produced give predictions of the number of spills to be expected in a year or bathing season using the historical rainfall record. The approach is therefore particularly suitable for use with spill frequency design criteria.

As with all modelling procedures, care must be taken to avoid using the process to investigate criteria outside the original assumptions. The SMARTS routine takes as its base time step an hourly interval. Its use for spills of less than this duration is questionable and therefore in very small catchments an alternative methodology may be required, based on an actual time series of rainfall.

A report is now available on the relative accuracies of the spill reductions procedure by the three methods. Assessments have been made of the individual spill volumes, associated storage volumes and the use of a median UCWI value. The accuracy of the methods used by the sewerage undertaker should be considered when determining the consent.

MINIMUM LENGTH OF RAINFALL RECORD

The method recommends that the minimum length of the rainfall record should be 10 years.

Such long records are not available for all parts of England and Wales. The method also includes advice on how to deal with shorter records.

Whatever the length of record available an assessment of the relative wetness of the period should be made against established long rainfall records. This will ensure any undue bias to wet or dry periods is avoided in making the assessment.

REFERENCES

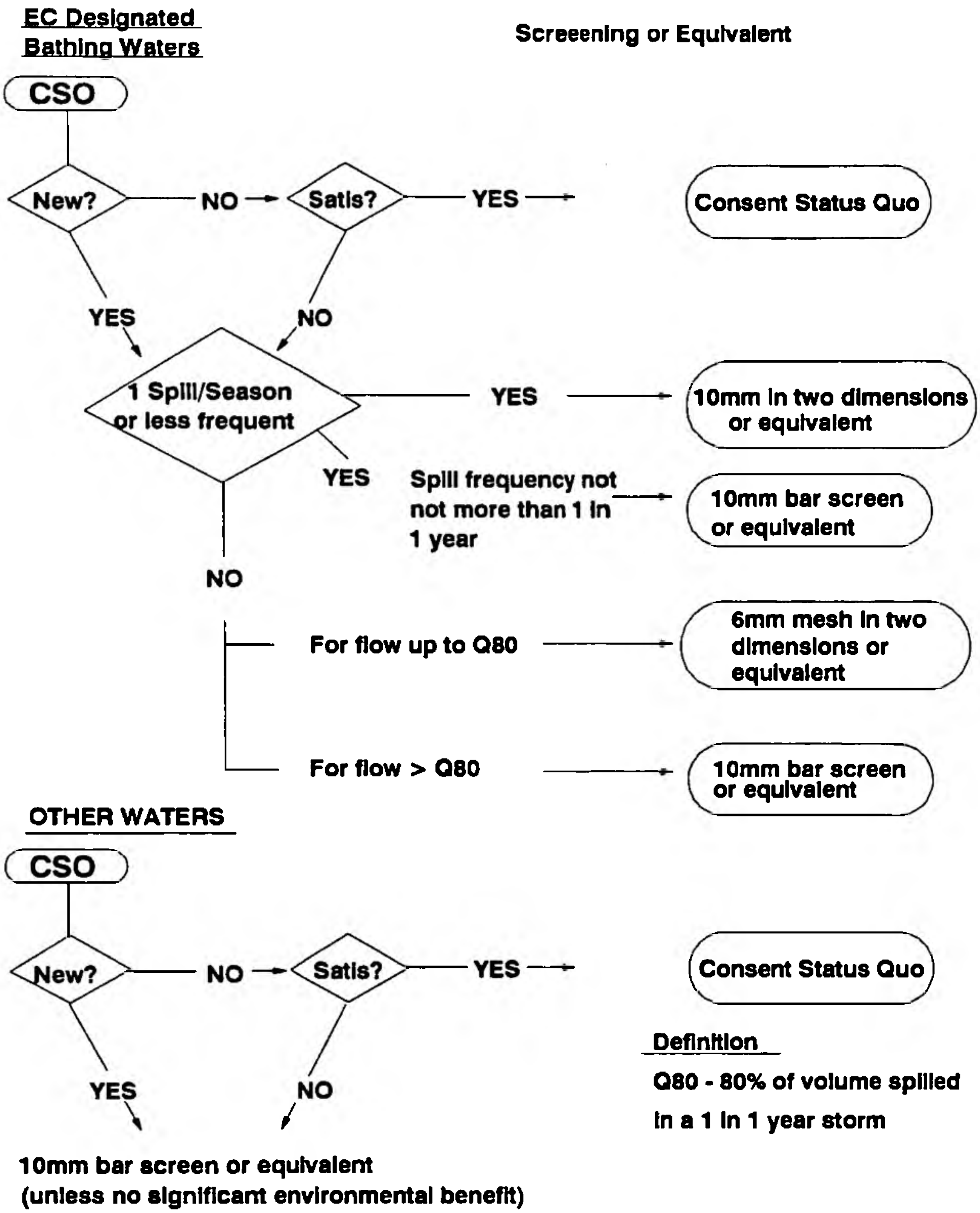
CSRG (1990) Estimating the frequency of operation of storm outfall and overflows - Method 1. CRSG Report No 5 WRc Report No C408 March 1990.

CSRG (1990) Estimating the frequency of operation of storm outfalls and overflows - Method 2. CRSG Report No 4 WRc Report No C409 March 1990.

CRSG (1991) Recommended Method for estimating storm discharge volumes and frequencies. CSRG Report No 12 WRc Report No UC10106 March 1991.

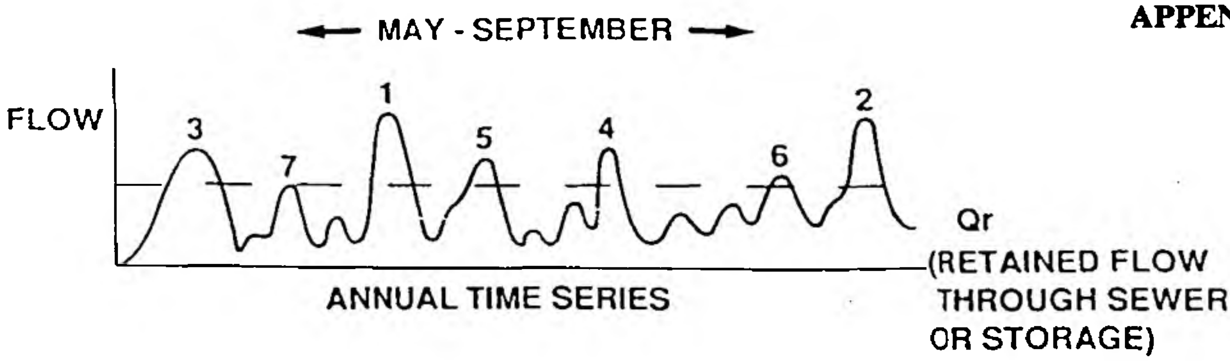
CSRG (1991) An Investigation of error bands associated with different spill prediction methods. CSRG Report No 14 WRc Report No UC1338 December 1991.

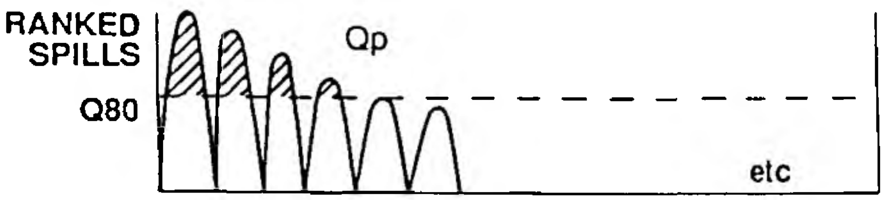
CONTROL OF DISCHARGE OF SOLIDS COASTAL WATERS & ESTUARIES



AESTHETIC CONTROL REQUIREMENTS FOR C.S.O's INTO COASTAL WATERS & ESTUARIES

APPENDIX D





Total volume - Area under curve

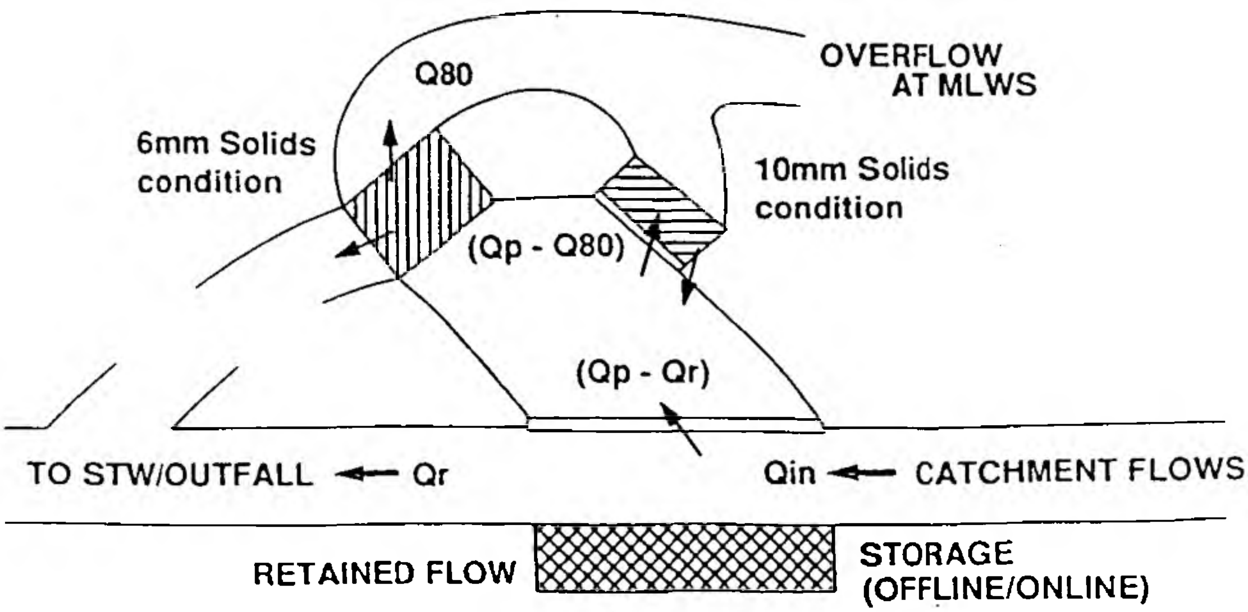
Q80 - (80% of total volume) flow

Where Qp >> Q80 then Q80 - 6mm Solids condition

(Qp - Q80) - 10mm Solids condition

Where Qp >> Q80 then 6mm for all flows

TYPICAL INSTALLATION



ANNEX 1

GUIDANCE ON STANDARDS FOR UWWTD

1. DoE are chairing an EC UWWTD Implementation Group which will issue definitive guidance. However, the following provisional guidance should be used until the definitive guidance is available.

2. All waters should be assumed to be normal unless designated sensitive or less sensitive and require secondary treatment of continuous sewerage discharges.

3. The designation of sensitive and less sensitive areas will be agreed by the Secretary of State. Until these are defined, the existing notification by DoE through the UWWTD Implementation Group will apply, and should be used to identify the exceptions to secondary treatment for the purposes for the Directive.

4. Standards to apply:

Primary Treatment:		A 50% reduction in load of suspended solids, and 20% of BOD (maximum spot standard of 500 mg/l suspended solids unless the crude sewage is of unusual character).
Secondary Treatment:	COD	125 mg/l 95%ile composite; and 250 mg/l absolute composite; or alternative % removal according to directive.
	BOD	25 mg/l 95%ile composite (equivalent to 31 mg/l 95%ile spot sampled standards); and 50 mg/l absolute composite.

5. Indicative consent standards should be such that COD and suspended solids and spot absolute standards should not determine the extent of treatment and therefore cost of investment unless there are specific environmental reasons.

6. For works serving >2,000 pe and discharging to estuarial or freshwaters and for works serving >10,000 pe and discharging to normal or sensitive or coastal waters, then where existing BOD (ATU) standards are less than 31 mg/l, investment to meet the UWWTD is not required. Where present or future calculated standards are greater than 31 mg/l, BOD (ATU) as 95%ile spot standards then the UWWTD standard should apply.

7. Where a works serving >10,000 pe discharges to a sensitive area it will be necessary to control the discharge of nutrients. The standard to apply will be:

Freshwaters

2 mg/l P (10,000 - 100,000 pe);
1 mg/l P (>100,000 pe).

These will apply to areas designated by the Secretary of State as requiring action.

15 mg/l N (10,000 - 100,000 pe);
10 mg/l N (>100,000 pe).

These will apply to areas designated as eutrophic. However, there are currently no proposals to control nitrogen in eutrophic areas. There may be a requirement to reduce nitrogen discharges to waters which exceed the 50 mg/l NO_3 standard and which are used for drinking water abstraction, but these standards have not yet been resolved by the DoE.

Marine Waters

15 mg/l N (10,000 - 100,000 pe);
10 mg/l N (100,000 pe).

These will apply to areas designated as eutrophic.

ANNEX 2

CALCULATION OF RIVER NEEDS CONSENTS BY CD-METHODS

CONTENTS

SECTION 1: INTRODUCTION

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.

1.2 In order to protect our water supplies, our wildlife and the centre of much of our recreation, and impose no unnecessary costs on dischargers and abstractors, it is important to calculate correctly and fairly the measures needed to protect river quality and achieve further improvement.

1.3 This report is a guide on calculating the standards for discharges which are needed to ensure that river quality is maintained and Water Quality Objectives are met. It will be useful to those who set Consents (and to those who work out the effect of abstractions on river water quality).

1.4 Section 2 deals with the calculation of Consents. Section 3 covers the more complex calculation of the discharge standards needed to meet river standards for Free Ammonia. Section 4 discusses preliminary work on intermittent discharges.

SECTION 2: CALCULATION OF CONSENTS

INTRODUCTION

2.1 This Section describes the calculation of Consents for continuous discharges. In this we are dealing with the Consents required to achieve **Water Quality Objectives** in rivers.

2.2 The Section can be used as a guide for the computer programs (WARNB, MCARLO, TIMCAT, or the equivalent).

2.3 Section 3 deals with the more complex calculations for the river standards for Free (or Un-ionised) Ammonia. Similarly, the more complicated calculation of the Consents for intermittent discharges are covered in Section 4.

2.4 For some catchments we may need to use a Catchment Model like SIMCAT or TOMCAT. This Section will help you decide which catchments.

METHOD OF CALCULATION

2.5 The calculations are based on the **Mass-Balance Equation**:

$$T = \frac{FC + fc}{F + f} \qquad .... \quad [1]$$

where: F is the river flow upstream of the discharge;
C is the concentration of pollutant in the river upstream of the discharge;
f is the flow of the discharge;
c is the concentration of pollutant in the discharge; and,
T is the concentration of pollutant downstream of the discharge.

2.6 The commonly used quality standards for rivers are 95%iles (or 90%iles) for the BOD and Total Ammonia. The Water Quality Objectives will be achieved with the required degree of reliability so long as the 95%ile is exceeded for no more than 5% of the time.

2.7 Similarly, Consents are defined as percentiles.

2.8 A single application of Equation [1] cannot be used to calculate the Consents needed to meet river targets. There are two ways to calculate correctly the relation between mean and percentile values of T and the Consent. These are called methods of **Combining Distributions (CD-Methods)**. They produce the distribution of T by combining the distributions of F,C,f and c.

2.9 The first method is the **Warn-Brew Method**. In this, the problem is set out algebraically and the variables F,f,C and c are presumed to follow a **Log-normal Distribution**. Generally the variables are assumed to be **independent** though **correlation** between F and f can be modelled.

2.10 The second method is **Monte-Carlo Simulation**. In this, a value for each of the variables F,C,f and c is plucked randomly from the full range of possible values (ie from the distributions). A value for T is calculated from each set of values of F,C,f and c using Equation [1]. The sequence of random selection and mass balance is repeated until enough values of T have been calculated to define its distribution. Each value of T (or each value of F,C,f or c) is called a **shot**. Typical calculations have 500 shots.

2.11 In the Monte-Carlo method it is common to assume that F,C,f and c follow the Log-Normal distribution but other distributions can be used. With this method you can also introduce **all** the possible correlations between F,C,f and c.

2.12 The CD-Methods are used on a computer. You respond to questions displayed on a terminal by typing in data. The calculation is then done by the computer and the results shown on the terminal. The results can be printed, or you can use a word processor to transfer them to your reports.

2.13 Programs WARNB and MCARLO are available for use with the IBM pc (or compatible) and have been used since the middle 1970s for the calculation of Consents and for Catchment Planning. Examples of the output are shown in Appendix 2.1.

2.14 The Warn-Brew Method is often used for routine calculations because it is quicker.

2.15 Monte Carlo Simulation can be applied to a wider range of problems than the Warn-Brew Method. These include the effects of all possible correlations (as mentioned above) and the effects of assumptions that the data are Log-Normal. Also, the Monte-Carlo method can be used to calculate the effect on river quality of abstractions which reduce the flow in rivers upstream of polluting discharges. It can also evaluate options to control of river quality by adding to river flow.

2.16 The CD-Methods may be used **forwards** (to calculate the river quality downstream of some particular discharge quality) or **backwards** (to calculate the Consent needed to achieve a target quality in the river).

DATA

2.17 The CD-Methods require data which characterise the distributions of the variables F, C, f and c. In most cases, the data can be presumed to be log-normally distributed. This means that two summary statistics will define the complete distribution. Any two statistics may be used, so it is best to use those readily available. These are:

- River flow: mean and 5%ile;
- Upstream river quality: mean and standard deviation;
- Discharge flow: mean and standard deviation; and,
- Discharge quality: mean and standard deviation or mean and 95%ile.

2.18 The river target is usually a 95%ile although any other percentiles (and the mean) can be specified.

2.19 It is tempting just to compute the summary statistics and get on with the calculations. There is a risk in this which can be avoided by using packages like AARDVARK or PILCHARD to inspect the raw data in the form of graphs. This will show up peculiarities, like outliers, which might have produced summary statistics which were misleading.

2.20 The results of most calculations are unaffected by the assumption that the data follow Log-normal Distributions. However, you can use AARDVARK to display the data as histograms and to test which distributions provide the best fit to the data. With experience, this will show the cases where it would be risky to assume a particular distribution.

2.21 The advice in these last two Paragraphs is particularly important when calculating Consents other than BOD and Ammonia.

2.22 There will always be uncertainties with these four sets of data and the associated assumptions of distribution and correlation. Where there are gaps in knowledge you should make neutral assumptions and check the sensitivity of your results to the uncertainties in data. Often you will find the results unaffected. You should avoid making pessimistic assumptions because the effect of these can accumulate and produce proposals for Consents which are stricter than needed to meet the river targets.

2.23 If you are unhappy to assume the Log-Normal distribution you can use other distributions with MCARLO or you can use Catchment Models. Also, a version of MCARLO, called NCARLO, allows you to use **any** distribution for river flow. Another version, NNCARLO, allows any distribution for river flow, river quality, discharge flow or discharge quality. The programs are discussed in Appendix 2.4.

2.24 Some discharges enter a stream close to the confluence with another watercourse. Here, the calculation must take account of the river targets of both rivers. One way of handling this is discussed in Appendix 2.2, but it may be better to use a Catchment Model.

2.25 Some discharges enter a stream close to the confluence with other discharges. Here, also, it may be best to use a Catchment Model.

River Flow

2.26 Hydrologists are accustomed to being asked to provide estimates of river flows for locations upstream of discharges (Appendix 2.3).

Upstream River Quality

2.27 If you check the sensitivity of your results to the data you will find that the data on the upstream river quality and the river target will often be the most important source of uncertainty in most calculations.

2.28 You should be aware of the statistical uncertainty in your data. You can calculate confidence limits on the estimates of the 95%iles (using programs like LNCL, for example).

2.29 It is sobering to calculate the uncertainty in estimates of 95%iles. Take Ammonia for example. An estimate of a 95%ile can easily have a 90% confidence interval from -50% to +100% if based on 36 samples. This uncertainty is caused by the Laws of Chance in sampling and presumes no additional errors in chemical analysis.

2.30 The mean and standard deviation are required for river quality just upstream of the point of discharge. To avoid the effects of unusual hydrology or small sets of data, it is best to use results obtained, say, over 3-4 complete years.

2.31 Where the nearest monitoring point is some distance upstream, it can be important to allow for the effects of natural purification from the monitoring point to just upstream of the discharge. This can be calculated from river quality data for pairs of monitoring points located on the same or a similar river:

If an upstream mean quality is C_1, and that D km downstream is C_2, then a corresponding "rate constant", K, is given as:

$$C_2 - C_o = (C_1 - C_o)e^{-kD}$$

or:

$$k = \frac{\ln[\,(C_1 - C_o) \,/\, (C_2 - C_o)\,]}{D}$$

Where C_o is the concentration expected in an unpolluted river. For Ammonia, C_o would be zero, For the BOD a value of 1 mgl^{-1} might be more appropriate.

The rate constant, k, can be used to estimate mean river quality immediately upstream of the discharge from data for a point further upstream. The corresponding standard deviation is best calculated by preserving the ratio of standard deviation to mean.

2.32 Where no upstream quality data are available, you can use those from neighbouring or similar rivers. Alternatively, you may prefer to assume that the upstream river lies in the middle or in the best quarter of its (presumed) Class. Faced with the sampling errors illustrated by Paragraph 2.29, you may feel safer with estimates of upstream quality which are based on the presumed Class.

(Program MIDCL, or the equations in Appendix M.1, allow you to set up a mean and standard deviation which corresponds precisely to a particular percentile)

2.33 We need to be careful in cases where the calculation is sensitive to assumptions and data. In these, it is unreasonable to expect a discharger to spend a lot of money on a discharge where we have failed to collect data on the upstream river and so made neutral or pessimistic assumptions about its quality. The collection of these data requires pre-planning. If our preliminary calculations indicate a need to improve the discharge, we should plan to obtain data for the upstream quality of the river.

2.34 We should not normally require a discharge to have tight standards just because pollution upstream of the discharge provides poor quality river water for dilution. We should assume the upstream discharges will be improved so that the stretch of river achieves its Objectives. If we need to consider the downstream discharge in advance of this happening, we should assume the upstream river lies in the middle of its Objective Class (see Appendix M.1).

2.35 Alternatively, we can use a Catchment Model to set Consents in one go for all the discharges in the catchment. For important catchments and important discharges we shall want to do this anyway.

Discharge Flow

2.36 You need the **Mean Daily Flow** and the standard deviation. For discharges which are gauged you should avoid data for part-years because of the seasonal variation.

2.37 For quickness, the mean daily flow is often estimated as 1.25 times the **Dry Weather Flow**. The standard deviation is seldom a critical factor and can often be taken as one third of the mean daily flow. Both of these factors will be larger for works which are overloaded.

2.38 When a works is to be extended, you will have to use estimates of future flow. Here, it is probably adequate to base the estimates on the expected Dry Weather Flow of the new works (see the last paragraph).

Discharge Quality

2.39 In the calculation of the Consent (the backwards calculation), you may be surprised that the CD-Method asks you for the discharge quality. After all, you want to calculate the discharge quality needed to meet the river target.

2.40 The values you enter for the backwards calculations are used only as a starting point. It is important only that the **ratio** of mean to standard deviation is sensible. Outside this constraint, the actual values of the mean and standard deviation entered are unimportant.

2.41 It is a good idea to start with the mean and standard deviation for the current quality of the discharge. If the calculated Consent turns out to be tighter than the current quality you should repeat the calculation. This time start with the mean and standard deviation for a discharge which is typical of the type of works which will be needed to achieve the calculated Consent.

Precision Required of Data

2.42 Generally, the sensitivity of your results to data is far smaller than the statistical errors associated with sampling programmes (Paragraph 2.29). Exceptions are discussed in Paragraphs 2.55 onwards. Two general points are made here:

- it is quicker to repeat a calculation to gauge whether the Consent is sensitive to the data, than to produce data to a prejudged impression of required accuracy; and,

- any sensitivity to data reflects real uncertainty about the decisions needed to achieve the river target. It is not a consequence of the method of calculation.

DOING THE CALCULATIONS

2.43 It is straightforward to enter your data and calculate the Consent (see the examples in Appendix 2.1). It is usually essential do more than one calculation. They take so little extra time.

2.44 When you finish a calculation, programs like MCARLO will ask whether you want to change some of the data and do a repeat. A sequence of menus allows you to change the flow and quality of the river and discharge, check the effect of assumptions of distribution, investigate the consequences of correlation, or examine the importance of changes to river flows caused by abstraction or additions.

2.45 It is helpful, before rounding, to check the downstream river quality produced by common discharge standards like 20 mg/l of BOD and 10 mg/l of Total Ammonia.

2.46 Important tests are:

- the change in the Consent caused by a small alteration in the river target or the upstream river quality; and

- the change in the downstream river quality caused by a variation of the discharge quality and flow.

2.47 When the data are poor and the calculations give a strict Consent then you must also check the effect of:

- a change in the ratio of standard deviation to mean in the discharge quality; and

- more optimistic assumptions about the quality of the upstream river.

2.48 Similarly, you may want to check the effect of **correlation**, especially that between river flow and:

- discharge flow; or,
- discharge quality (especially for Ammonia).

(To check any correlation apart from that of river flow on effluent flow you must use the Monte Carlo Method, MCARLO. A mathematical background to correlation is given in Appendix M.3)

2.49 If the calculated Consent for an important discharge is sensitive to **correlation** then it is prudent to calculate the actual correlation coefficients. You can do this by Linear Regression of the logarithms of the variables. The coefficient provided by this is the one required by MCARLO. A programme for doing this is available (REG).

2.50 Finally you may want to satisfy yourself that the calculated Consent is insensitive to the assumption that river flows are Log- Normal. You can do this with MCARLO, though you can use NCARLO to look at any distribution for river flow. (Also, you can use NNCARLO to look at any distribution for any of the Mass Balance variables - Appendix 2.4).

2.51 It is useful to calculate the river quality produced downstream of the current discharge (the forwards calculation). This shows the effect of the discharge relative to other sources of pollution.

2.52 You may be able to compare this estimate of river quality with an estimate based on actual measurements of river quality downstream of the discharge. This may re-assure you that the calculations are correct but you should be prepared for big differences because of statistical Sampling Error in the data for river (and discharge) quality (Paragraph 2.29). The calculated river quality is often a better estimate of the true summary statistics for river quality downstream of the discharge than that obtained from the analysis of samples of the river water itself.

2.53 In some cases there may be **statistically significant** differences between the results of the Mass Balance calculation and the measured quality in the river. This will indicate errors in the data used in the Mass Balance calculation or sources and sinks of pollution which may need to be taken into account in our plans to meet Water Quality Objectives.

2.54 It may also indicate more subtle effects like those caused by the fact that we take most of our samples between the hours of 10.00 and 15.00. Because of the time taken for a volume of river water to travel, our day-time river monitoring may tend, for example, to record in the river the effects of the effluent load discharged at night. This called the effect of **Sample Window**. It is well known that effluent load varies throughout the day.

2.55 To counter the effect of Sample Window you might choose to alter your sampling procedures or to move the sampling point on the river. Also, the

Catchment Model, TOMCAT, can be used to calculate the effects of Sample Window.

INTERPRETING THE RESULTS

2.56 The calculations define, correctly, the effect of a discharge on a river. If the results appear anomalous then the reasons for this will be of practical significance. The following paragraphs describe some of the types of results which require special care in interpretation.

Failure to Achieve the River Target

2.57 The quality which you entered for the river upstream of the discharge can sometimes be worse than the river target required downstream. The Consent will then have to be similar or better than the quality of the river in order to achieve the target required in the river. In some cases it may be impossible to meet the river target even if the discharge quality were set to a concentration of zero.

2.58 The interpretation of this result is that the river target cannot be met unless river quality is improved upstream of the discharge. However, this type of result can be produced if you:

- use a river target which is too strict;
- neglect to allow for improvements to upstream discharges; or,
- ignore natural purification.

In these cases the results point out the consequences of your assumptions. They show where a sensible Consent can be set only if you consider the combined effect of several discharges. (You can do this in a systematic series of calculations starting at the upstream discharges but it would save a lot of time to use a Catchment Model).

2.59 Calculated Consents which are too strict can result if the data on the upstream river quality are corrupted by the effects of algae on the BOD test. Rivers which are affected strongly by algae show enhanced levels of Chlorophyll-a and levels of Dissolved Oxygen in excess of 100% saturation. Generally, sluggish rivers may be suffering this effect if they show high measurements of BOD in summer, no evidence of sanitary pollution, and good biology. In these cases it may be better to use in the calculation, summary statistics for the BOD of the upstream river which are consistent with assuming that the river lies in the middle or in best quartile of its presumed Class (as calculated without BOD) (see Appendix M.1).

Results which are Sensitive to Data

2.60 This condition will occur in many calculations like those discussed in

Paragraph 2.56. When the upstream quality is close to river target, there is only a small capacity for the river to take more pollution. This capacity may increase several fold if the data for the calculation are changed slightly.

2.61 The interpretation of these results is as in Paragraph 2.57. You should look at the data on the quality of the river upstream of the discharge and check whether this is close to the target required downstream of the discharge.

2.62 The calculated Consent can also be sensitive to data where the river provides enormous dilution. What may happen is that the calculated Consent will change markedly following a slight change to the river target or upstream river quality. This result will occur when the discharge is so small as to have a negligible effect on river quality.

2.63 Often the effect of this will be limited by the use of Minimum Standards (Paragraph 2.5). But the interpretation is that the Consent can be set without regard to the target in the receiving stream. You can check this by calculating the river quality downstream of various values of the discharge quality.

2.64 Occasionally you may set up a calculation which combines an upstream river quality which is worse than the target with enormous dilution of the discharge flow by the river. Here the calculated Consent can be very sensitive to data although the downstream river quality will be almost independent of discharge quality.

In practice the Consent can be set without regard to the river target. Again you can check this point by calculation.

Discharges with Little Dilution

2.65 When the 5%ile river flow is zero or some small proportion of the discharge flow, the calculated Consent will come out close to the concentration entered for the river target. This reflects the fact that where there is no dilution from the river, the Consent must be the same as the river target.

2.66 If this is unacceptable, you will either have to live with failure to meet the river target or insist that the discharge goes elsewhere.

2.67 Some decisions of this type depend on whether a small watercourse is important enough to be treated as a river and so have Water Quality Objectives.

RIVER FLOW: ADDITIONS AND ABSTRACTIONS

2.68 Although this report deals with the calculation of Consents, you may be asked for a view on proposals to add or abstract river flow upstream of a discharge. The effects of schemes which augment river flows can be assessed using MCARLO, NCARLO, NNCARLO (or SIMCAT). Schemes which augment river flows may be operated, for example, to add flows so that the river flow never drops below a set minimum level.

2.69 The results will show that, compared with improving effluent quality, the augmentation of low river flows is usually a poor method of achieving the river target.

2.70 Similarly, you may be asked to assess the consequences of a proposal to remove river flow at a point upstream of a discharge. This may affect the Consent because dilution is reduced.

2.71 As mentioned in Paragraph 2.49, the effects of activities which alter river flows can be assessed by changing the flow data used in the calculation and by changing the statistical distribution assumed for river flow. The latter requires that you use MCARLO (or SIMCAT). (If the change is particularly big it will be better to use NCARLO or NNCARLO. These allow you to check the impact of any change to river flow and make no assumptions about the distribution of river flow).

USING THE RESULTS

2.72 The CD-Methods allow you to assert that the Consent is required in order to achieve a river target and that the condition is not stricter than needed.

2.73 Given good data, and in some cases even with poor data, this assertion will be objective and categoric and one which a discharger could demonstrate to himself.

2.74 Sampling programmes must be geared up to provide good data for important decisions. This will require planning.

2.75 You should keep records of the data used to calculate Consents and of the results. This will simplify the review and update of the calculations.

REFERENCES

For a technical background to the CD-Methods see:

Warn, A.E. and Brew, J.S. 1980. Mass Balance. Water Research, 14, 1427-1434.

APPENDIX 2.1 EXAMPLES OF CALCULATIONS

Mass Balance Calculation		Monte-Carlo Simulation
Discharge: River: Pollutant:	Kinnersley STW River Clean BOD	
Input Data		
Mean river flow upstream of discharge		100.00
5%ile flow		20.00
Mean upstream quality		2.00
Standard deviation		1.00
95%ile quality		3.74
Mean flow of discharge		20.00
Standard deviation		8.00
Mean quality of discharge		15.00
Standard deviation		7.00
Results		
Mean river quality downstream of discharge		2.74
Standard deviation		1.10
95%ile river quality		5.00
River Quality Target (95%ile)		5.00
Mean quality in discharge		5.71
Standard deviation		2.86
50%ile discharge quality		5.13
80%ile discharge quality		7.55
90%ile discharge quality		9.54
95%ile discharge quality		11.22

Repeat calculation with maintained river flow	
Input data	
Mean river flow upstream of discharge	*** 100.00
5%ile flow	*** 20.00
Maintained river flow	*** 21.00
Results	
Mean river quality downstream of discharge	2.82
Standard deviation	1.12
95%ile river quality	5.00
River Quality Target (95%ile)	5.00
Mean quality in discharge	6.18
Standard deviation	3.10
50%ile discharge quality	5.55
80%ile discharge quality	8.17
90%ile discharge quality	10.32
95%ile discharge quality	12.14

Repeat calculation with shifted log-normal river flow data	
Input data	
Mean river flow upstream of discharge 5%ile flow Shift parameter	*** 100.00 *** 20.00 *** 7.00
Results	
Mean river quality downstream of discharge Standard deviation 95%ile river quality	2.74 1.10 5.00
River Quality Target (95%ile)	5.00
Mean quality in discharge Standard deviation 50%ile discharge quality 80%ile discharge quality 90%ile discharge quality 95%ile discharge quality	5.82 2.92 5.23 7.69 9.72 11.43

Repeat with correlation for log river flow on log discharge quality **Coefficient = .1500**	
Input data	
Mean river flow upstream of discharge 5%ile flow	100.00 20.00
Results	
Mean river quality downstream of discharge Standard deviation 95%ile river quality	2.89 1.11 5.00
River Quality Target (95%ile)	5.00
Mean quality in discharge Standard deviation 50%ile discharge quality 80%ile discharge quality 90%ile discharge quality 95%ile discharge quality	6.65 3.32 6.00 8.60 11.00 13.00

APPENDIX 2.2 Natural Purification

1. Some discharges enter a river close to the confluence with another watercourse. Here, the calculation must take account of the target quality in both rivers.

2. It may be important to allow for natural purification in the river which first receives the discharge so that we can check what is needed to meet the target in the second river. This can be done as follows:

   (a) establish the discharge quality needed to protect the first stream;

   (b) calculate the discharge quality needed to protect the second stream making no allowance for natural purification in the first stream (pretend the discharge is re-located to the second stream at the confluence with the first stream);

   (c) if the second assessment produces a result which is stricter than the first, calculate the effect of natural purification as described in Paragraph 13 in the main text;

   (d) the proportion of load remaining after natural purification is:

   $$1 - e^{-KD}$$

   (e) compare the results for the two streams and use the more strict to set the Consent.

3. Rate constants reported in the literature should not be used as these will seldom apply to summary statistics or to the local circumstances.

4. It is also important to avoid using rate constants measured by following a particular body of water downstream. Such constants do not define the effect of natural purification on statistics of river quality.

5. Alternatively, you can use SIMCAT for this type of calculation.

APPENDIX 2.3 River Flow

1. Two summary statistics are required to characterise the river flow distribution. The mean and the 5%ile flow are easiest to use. With the assumption of Log-Normality, these statistics define the full Flow Duration Curve.

2. If the flow data are not Log Normal then other distributions can be tried provided the Consent is calculated by MCARLO. Also, a version of MCARLO, called NCARLO, allows you to use **any** distribution for river flow. (You can also use SIMCAT or TOMCAT).

3. The statistics should be estimates from the long term average Flow Duration Curve. Ideally, historic flows should have been adjusted for the net effect of current (or projected) discharges and abstractions.

4. In studies of water resources, the 5%ile flow is often used to indicate the flow in dry conditions. Decisions on abstraction licences are sensitive to errors in the estimated value of this flow.

5. In river quality planning, the low flow is required, with the mean, solely to characterise the total distribution of flows. Results are sensitive to gross errors in the flow data but are not so dramatically affected by error in the low flow value itself.

6. This means that the flow data need not be as accurate as required for some water resource purposes. Where gauged data are lacking, estimates based on a knowledge of catchment area and type will usually be sufficient.

7. Small streams should not be given a zero flow just because they are of trivial importance to water resources. If a better estimate of the low flow is, say, 1 or 2 percent of the mean then this value should be specified even though this might be viewed as zero as a water resource.

8. In rivers affected by regulation schemes, you should use the Flow Duration Curve which includes flows added for water resource purposes.

APPENDIX 2.4 Non-parametric Distributions

1. Program NCARLO is the same as MCARLO except that you have the option to specify any distribution for river flow. You do this by telling NCARLO the name of a file on which you have placed data which define the distribution.

2. These data are points taken from the Flow Duration Curve. This can be any shape you like.

3. A set of output, and an example of a data-file, are shown in Table 2.4.

3. NCARLO is useful when looking at the effects of proposed abstractions (from rivers or groundwater) which may affect river flows upstream of discharges. In these cases you can simulate the effect of any proposal whose impact can be translated into an effect on the Flow Duration Curve (this should include everything).

4. A second program, NNCARLO, is similar to NCARLO, but you can also specify any distributions for river quality and discharge flow and quality.

TABLE 2.4: Output From NCARLO

Mass Balance Calculation	Monte-Carlo Simulation Non Parametric Distribution for River Flow
Calculations done at 9.03 on 23.12.91	
Discharge: Chubb STW River: River Bird Pollutant: BOD	
Input Data	
Mean river flow upstream of discharge 95% exceedence river flow	Non-parametric distribution 12.09 .00
Mean upstream river quality Standard deviation	2.00 1.00
Mean flow of discharge Standard deviation **Mean quality of discharge quality** Standard deviation	20.00 8.00 15.00 6.00
Results	
Mean river quality downstream of discharge Standard deviation 95%ile river quality 99%ile river quality	4.61 2.23 9.00 12.44
River Quality Target (95%ile)	9.00
Mean quality of discharge Standard deviation 80%ile quality of discharge 95%ile quality of discharge 99%ile quality of discharge	5.51 2.37 7.11 10.03 13.49

Data-file Used for Nonparametric distribution of river flow:

14 0. 0. 12. 34. 1. 2. 2. 2. 2. 0. 1.5 5.7 8.1 99.

The first value, 14, is the number of values of river flow which follow. The 14 items of data, after ranking, are assumed equi-spaced in terms of the Wiebull plotting positions, 1/(1+n), for the Cumulative Frequency Distribution. This means that the above 14 points are:

From data-file	0.	0.	12.	34.	1.	2.	2.	2.	2.	0.	1.5	5.7	8.1	99.
After ranking	0.	0.	0.	1.	1.5	2.	2.	2.	2.	5.7	8.1	12.	34.	99.
Rank, r	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Plotting Position	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93

SECTION 3: CALCULATION OF CONSENTS TO MEET STANDARDS FOR FREE AMMONIA

3.1 This Section, like Section 3, describes the calculation of Consents for continuous discharges to rivers. Section 3 dealt generally with the discharge standards needed to meet river standards. You could use Section 2 for BOD and Total Ammonia.

3.2 This Section gives the extra information needed for setting Consents for Total Ammonia which will achieve river standards for **Free (or Un-ionised) Ammonia**. It should be used in conjunction with Section 3.

3.3 Section 3, together with Section 2 provides a Guide for the computer program AMMONIA.

FREE AMMONIA

3.4 Ammonia dissolved in water exists mostly in the ionised form, NH_4^+, but some is present as un-ionised or Free Ammonia, NH_3. It is the latter which is particularly toxic to fish.

METHOD OF CALCULATION

3.5 To get the correct relation between the Consent and percentile values of Free Ammonia we have to use **Monte-Carlo Simulation**. This technique gives the effect on the **distribution** of river water quality of the **distribution** of Total Ammonia in the discharge.

3.6 Within the Simulation, there are two steps:

- we use the **Mass-Balance Equation** to calculate the effect of the discharge on the Total Ammonia in the river; and
- we use data on water chemistry to calculate the Free Ammonia provided by the calculated Total Ammonia (Appendix M.3).

3.7 The Mass Balance Equation is:

$$T_{TA} = \frac{FC_{TA} + fc_{TA}}{F + f} \quad \ldots . \quad [1]$$

where: F is the river flow upstream of the discharge;
C_{TA} is the concentration of Total Ammonia in the river upstream of the discharge;
f is the flow of the discharge;
c_{TA} is the concentration of Total Ammonia in the discharge; and,
T_{TA} is the concentration of Total Ammonia downstream of the discharge.

3.8 The proportion of ammonia present in the free form depends on the water chemistry, especially on the pH and the temperature (Appendix M.3). For calculations of Free Ammonia we need to provide more than F, C_{TA}, f and c_{TA}. We have to provide data on:

pH, Temperature, Alkalinity, Total Dissolved Solids and **Dissolved Oxygen** in the river.

In the Simulation, this is done by extracting values from each of the distributions of pH, Temperature, Alkalinity, Total Dissolved Solids and Dissolved Oxygen. These are used with the equations in Appendix M.3 to calculate the concentration of Free Ammonia at the fish gill which corresponds to each value calculated for the Total Ammonia, T_{TA}, downstream of the discharge.

3.9 In the Monte-Carlo method it is common to assume that F, C_{TA}, f and c_{TA} follow the Log-Normal distribution but other distributions can be used instead. You can also introduce all the possible correlations between F, C_{TA}, f and c_{TA}.

3.10 The distributions of pH, Temperature, Alkalinity and Total Dissolved Solids are assumed to be Normal.

3.11 Temperature is assumed correlated with river flow. If you have a little knowledge of FORTRAN you can change these assumptions (in the subroutine called INIT) and introduce correlations between any of the following:

Total Ammonia in the river or effluent, river flow, effluent flow, and in the river: pH, Temperature, Alkalinity, Total Dissolved Solids and Dissolved Oxygen in the river.

3.12 Program AMMONIA is available for use with the IBM pc (or compatible). Examples of the output are in Appendix 3.1. AMMONIA can be applied to the same wide range of problems as MCARLO. This is discussed in Section 3.

DATA

3.13 AMMONIA requires data which characterise the distributions of the variables. The data can be presumed to be normally or log- normally distributed. This means that two summary statistics will define the complete distribution. Any two statistics may be used, so it is best to use those readily available. These are:

Upstream river:	■ River flow:	mean and 5%ile;
	■ Total Ammonia:	mean and standard deviation;
Discharge	■ Discharge flow:	mean and standard deviation;
	■ Total Ammonia:	mean and standard deviation or mean and 95%ile.
Downstream river:	■ pH:	mean and standard deviation;
	■ Temperature:	mean and standard deviation;
	■ Alkalinity:	mean and standard deviation;
	■ Total dissolved solids	mean and standard deviation;
	■ Dissolved Oxygen	mean and standard deviation;
River Target	■ Free Ammonia	percentile.

3.14 If you lack data on Alkalinity, Total Dissolved Solids and Dissolved Oxygen press RETURN on being asked for the mean alkalinity. The calculation will then proceed with default values for these data:

- Alkalinity: mean = 200 mgl^{-1} standard deviation = 20 mgl^{-1};
- Total Dissolved Solids mean = 700 mgl^{-1}; standard deviation = 70 mgl^{-1}; and
- Dissolved Oxygen mean = 7.0 mgl^{-1}; standard deviation = 1.5 mgl^{-1}.

You can arrange to have these defaults set to values which suit your area (by changing three of the statements in subroutine GETALK)

3.15 The river target is usually a 95%ile although other percentiles can be used.

3.16 If you enter a river target which is bigger than 0.1 mgl^{-1} it will be interpreted as a standard for Total Ammonia and not as one for Free Ammonia. This allows you to flip between the standards for the two ammonia species as you decide the Consent.

3.17 You should use Section 2 for advice on topics like:

the precision required of data (Paragraph 2.41);
the interpretation of results (from Paragraph 2.55);
the sensitivity of results to data (from Paragraph 2.59);
river flows (from Paragraph 2.67) ; and
natural purification (Paragraph 2.30).

APPENDIX 3.1: EXAMPLES OF CALCULATIONS FOR FREE AMMONIA

Mass Balance Calculation for Ammonia	Monte-Carlo Simulation
Pollutant: Free and Total Ammonia (Enhanced Gill Model)	
Input data	
Mean river flow upstream of discharge	100.00
5%ile flow	20.00
Mean upstream total ammonia	0.10
Standard deviation	0.10
Mean flow of discharge	20.00
Standard deviation	8.00
Mean total ammonia of discharge	15.00
Standard deviation	7.00
Mean pH downstream of discharge	8.00
Standard deviation	0.40
Mean temperature downstream of discharge	11.00
Standard deviation	4.00
Mean alkalinity downstream of discharge	200.00
Standard deviation	20.00
Mean total dissolved solids	700.00
Standard deviation	70.00
Mean dissolved oxygen	7.00
Standard deviation	1.50
Results	
Mean total ammonia downstream of discharge	0.52
Standard deviation	0.29
95%ile total ammonia	1.09
Mean unionised ammonia downstream of discharge	0.0072
Standard deviation	0.0064
95%ile unionised ammonia	0.0205
River Quality Target (95.0%ile)	0.0205
Mean total ammonia in discharge	2.14
Standard deviation	1.07
80%ile total ammonia in discharge	2.81
95%ile total ammonia in discharge	4.21

Repeat calculation with different data	
Results	
Mean total ammonia downstream of discharge Standard deviation 95%ile ammonia total NH2	.69 .40 1.50
River Quality Target (95%ile)	*** 1.50
Mean unionised ammonia downstream of discharge Standard deviation 95%ile unionised ammonia	.0097 .0087 .0280
Mean total ammonia in discharge Standard deviation 80%ile total ammonia in discharge 95%ile total ammonia in discharge	2.97 1.48 3.89 5.83

Repeat calculation with different data	
Input data	
Mean pH downstream of discharge Standard deviation	*** 7.60 *** .40
Results	
Mean Total ammonia downstream of discharge Standard deviation 95%ile total ammonia	.89 .53 1.99
Mean unionised ammonia downstream of discharge Standard deviation 95%ile total ammonia	.0071 .0069 .0205
River quality target (95%ile)	.0205
Mean total ammonia in discharge Standard deviation 80%ile total ammonia in discharge 95%ile total ammonia in discharge	3.95 1.97 5.17 7.75

SECTION 4: INTERMITTENT DISCHARGES

4.1 This Section describes the calculation of standards for **Intermittent Discharges**. For the present, the Section should be regarded as illustrative.

4.2 In particular, it is assumed that the river quality standards may be expressed as 99-percentiles. This follows an idea from Welsh Region which says river quality will be satisfactory if:

- the 95%ile standard of x mgl^{-1} is met; and
- a 99%ile standard of 2 x mgl^{-1} is also met.

4.3 Generally an intermittent discharge will operate with a frequency which is low enough not to threaten a 95%ile standard. The 99%ile standard will usually be the limiting factor on intermittent discharges.

4.4 This Section, together with Section 3 provides a Guide for the computer program INCARLO.

METHOD OF CALCULATION

4.5 To get the correct relation between the effluent standard and percentile values of river quality we have to use **Monte-Carlo Simulation**.

4.6 The calculations are based on the **Mass-Balance Equation**:

$$T = \frac{FC + fc + vx}{F + f + v} \qquad \ldots\ [1]$$

where: F is the river flow upstream of the discharge;
C is the concentration of pollutant in the river upstream of the discharge;
f is the flow of the continuous discharge;
c is the concentration of pollutant in the continuous discharge;
v is the flow of the intermittent discharge;
x is the concentration of pollutant in the intermittent discharge; and
T is the concentration of pollutant downstream of the discharge.

4.7 To calculate the effect on the river of the intermittent discharge, INCARLO needs to know something about the frequency at which the discharge operates. This is done by asking you to specify the Percent of Days on which the discharge operates.

4.8 INCARLO assumes each Monte-Carlo Shot represents a day. To decide whether the discharge operates on a particular day, INCARLO selects a random number between zero and 1 and compares this with the proportion of days suggested by the value specified for the Percent of Days in Operation.

4.9 As usual in Monte-Carlo Simulation, a value for each of the variables F,C,f,c,v and x is plucked randomly from the distributions. Non-zero values of v will occur only on those days (for those sets of Shots) when the intermittent discharge is calculated as operating. A value for T is calculated from each set of values of F,C,f,c,v and x using Equation [1]. The sequence of random selection and mass balance is repeated until enough values of T have been calculated to define its distribution.

4.10 As before, it is common to assume that F,C,f and c, as well as v and x, follow the Log-Normal distribution but other distributions can be used. INCARLO permits the use on Non-parametric distributions for the flow of the intermittent discharge.

4.11 You can also introduce **all** the possible correlations between F,C,f,c, v and x. You can also arrange that the overflow operates when river flows are high (or low) by specifying the correlation between river flow and the random number used to decide whether the discharge operates.

4.12 Program INCARLO is the same as MCARLO apart from the input and output for the intermittent discharge. INCARLO is available for use with the IBM pc (or compatible). Examples of the output are in Appendix 4.1.

4.13 INCARLO can be applied to the same wide range of problems as MCARLO. All this is discussed in Section 3.

DATA

4.14 INCARLO requires data which characterise the distributions of the variables. The data can be presumed log-normally distributed:

Upstream river:	■ Flow:	mean and 5%ile;
	■ Quality:	mean and standard deviation;
Continuous Discharge	■ Flow:	mean and standard deviation;
	■ Quality:	mean and standard deviation or mean and 95%ile;
Intermittent Discharge	■ % days in operation	
	■ Flow:	mean and standard deviation;
	■ Quality:	mean and standard deviation or mean and 95%ile.
River Target	■ Quality	percentile.

4.15 By entering data for both the continuous and the intermittent discharge you can calculate the effects on river quality of both discharges. If you enter zero when asked for the flow of the continuous discharge you can compute the effect of an intermittent discharge operating alone.

4.16 When you specify a River Target, INCARLO will try to meet it by changing the quality of the continuous discharge. To calculate the type of intermittent discharge needed to meet particular 99%iles of river quality you must use a process of trial-and-error.

APPENDIX 4.1: EXAMPLE OF CALCULATION FOR INTERMITTENT DISCHARGES

Mass Balance Calculation	Monte- Carlo Simulation
Calculations done at 9.06 on 20.12.91	
Discharge: Chave STW River: River Seager Pollutant: BOD	
Calculation of the river quality downstream of the input discharge quality	
Input data	
Mean river flow upstream of discharge	100.00
95% exceedence river flow	20.00
Mean upstream river quality	2.00
Standard deviation	1.00
Mean flow of continuous discharge	20.00
Standard deviation	8.00
Mean quality of discharge	15.00
Standard deviation	7.00
Mean flow of intermittent discharge	7.00
Standard deviation	4.00
Percent time in operation	6.00
Mean quality of intermittent discharge	200.00
Standard deviation	60.00
80%ile of intermittent quality	.00
95%ile of intermittent quality	.00
98%ile of intermittent quality	210.89
99%ile of intermittent quality	262.35
Results	
Mean river quality downstream of discharge	5.32
Standard deviation	3.23
95%ile river quality	11.84
98%ile river quality	14.99
99%ile river quality	17.24
80%ile discharge quality	20.35
95%ile discharge quality	30.23

APPENDIX M: Mathematical Background

APPENDIX M.1: Calculation of Standard Deviation from Mean and Percentile

In this Appendix we give equations for the calculation of the standard deviation, s, given the mean, m, and the 95%ile, q. The equations apply to the Log-normal Distribution and will be useful in calculations in which you want to assume that the river quality upstream of a discharge lies, for example, in the middle of its General Class.

k = Coefficient of Variation, s/m
d = Standard Normal Deviate for 95%ile = 1.6449
M = mean in the log domain
S = Standard deviation in the log domain

Step 1: $S = d - \sqrt{ d^2 + 2 \ln(m/q) }$
Step 2: $s = m * \sqrt{ e^{S^2} - 1 }$

Proof:

By definition:	$q = e^{(M + dS)}$
Take logs and re-arrange:	$\ln(q) - M - dS = 0$
And since:	$M = \ln [m / \sqrt{(1 + k^2)}]$
Then:	$\ln(q) - \ln(m) + ½\ln(1 + k^2) - dS = 0$
And since:	$S^2 = \ln (1 + k^2)$
We get:	$½S^2 - dS - \ln (m/q) = 0$
This is a quadratic.	
The solutions are:	$S = d \pm \sqrt{ d^2 - 4 (½) [-\ln(m/q)] }$
	$= d \pm \sqrt{ d^2 + 2 \ln(m/q) }$

Example:

For d = 1.6449; m = 2.0; q = 4.0:	
	$S = 1.6449 \pm \sqrt{2.7057 - 1.3863}$
	= 0.4962 or 2.7936
Now:	$k = \sqrt{ e^{S^2} - 1 }$
Therefore	k = 0.6284 or 49.4962
And:	s = k * m
	= **1.2568** or 98.9924

Obviously, s = 1.2568 is the sensible solution for BOD ...

Check:

For first root, S = 0.4962:	$M = \ln(m) - ½S^2 = 0.5700$
So:	$Q = M + dS = 1.3863$
And:	$q = e^{1.3863}$
	= <u>4.000</u>
and for, second root, S = 2.7936:	
	$M = \ln(m) - ½S^2 = -3.2090$
So:	$Q = M + dS = 1.3862$
And:	$q = e^{1.3862}$
	= <u>4.000</u>

APPENDIX M.2: CORRELATION

1. In MCARLO, Normal Random Deviates, N, are used to calculate values for variables like river flow, for instance, by assuming a Log- Normal Distribution. For example, the river flow, F, is:

$$F = \exp(m + N s) \quad \ldots \quad [1]$$

where m and s are the mean and standard deviation of the logarithms of F.

2. For two correlated variables, river flow, F and river quality, C, we need pairs of Normal Random Deviates, L and N. Before using N and L in Equation [1], the correlation between F and C is imposed by calculating M where:

$$M = N \phi + \sqrt{(1 - \phi^2)} L \quad \ldots \quad [2]$$

where ϕ is the correlation coefficient between M and N. Values of F and C are then calculated from Equation [1] as:

$$F = \exp(m_F + M s_F) \quad \ldots \quad [3]$$

$$C = \exp(m_C + N s_C) \quad \ldots \quad [4]$$

3. The value of ϕ lies between zero and unity. It may be estimated from real data because it is the same as the correlation coefficient produced by Linear Regression of the logarithm of F on the logarithm of C. To demonstrate this, we note that the correlation coefficient, R, is defined as:

$$R = \frac{\Sigma (X - m_X)\ (Y - m_Y)}{\sqrt{[(X - m_X)^2 (Y - m_Y)^2]}} \quad \ldots \quad [5]$$

Where: $X = \log F$, and $Y = \log C$

Substituting for X and Y, using Equations [3] and [4] gives:

$$R = \frac{\Sigma M N}{\sqrt{[M^2 N^2]}} \quad \ldots \quad [6]$$

which, since the means of M and N are zero, is the definition of the correlation coefficient between M and N.

4. In the Mass Balance Equation, there are not two but four variables, the flow and quality of the river, F and C, and the flow and quality of the effluent, f and c. All these may be correlated.

5. Suppose w, x, y and z were four independent sets of random numbers each with mean 0 and standard deviation 1. We need four further sets of random

numbers, W, X, Y and Z, such that the correlation between W and X is p_{WX}, that between X and Z is p_{XZ}, and so on for W and Z, Z and Y to give a total of 6 coefficients.

6. We can define the relation between the independent and correlated variables as:

$$W = w$$
$$X = b_1w + b_2x$$
$$Y = c_1w + c_2x + c_3y$$
$$Z = d_1w + d_2x + d_3y + d_4z \quad \ldots \quad [7]$$

for which we must determine the values of the 9 coefficients b_1, b_2, c_1 etc.

7. Nine conditions on these 9 parameters are:

To give the correct correlations:

$$p_{WX} = b_1 \qquad p_{WZ} = d_1$$
$$p_{WY} = c_1 \qquad p_{YZ} = b_1d_1 + b_2d_2$$
$$p_{XY} = b_1c_1 + b_2c_2 \qquad p_{XZ} = c_1d_1 + c_2d_2 + c_3d_3$$

and to give the correct standard deviations:

$$b_1^2 + b_2^2 = 1$$
$$c_1^2 + c_2^2 + c_3^2 = 1$$
$$d_1^2 + d_2^2 + d_3^2 + d_4^2 = 1$$

8. These conditions lead to the solutions:

$$b_1 = p_{WX} \qquad c_1 = p_{WY}$$
$$b_2 = \surd(1 - b_1b_1) \qquad c_2 = (p_{XY} - b_1c_1)/b_2$$
$$c_3 = \surd(1 - c_1^2 - c_2^2)$$
$$d_1 = p_{WZ}$$
$$d_2 = (p_{YZ} - b_1d_1)/b_2$$
$$d_3 = (p_{XZ} - c_1d_1 - c_2d_2)/c_3$$
$$d_4 = \surd(1.0 - d_1^2 - d_2^2 - d_3^2) \quad \ldots \quad [9]$$

9. A full set of solutions is feasible only if:

$$c_1^2 + c_2^2 < 1 \text{ and}$$
$$d_1^2 + d_2^2 + d_3^2 < 1 \quad \ldots \quad [10]$$

10. So, given values for the 6 correlation coefficients between W, X, Y and Z, we can calculate the coefficients b_1, b_2, c_1 etc. We can then use Equations [7] to compute the correlated deviates from the uncorrelated, independent values of w, x, y and z.

Example:

Suppose that the river flow is correlated positively with effluent flow. This would happen if both were affected by rainfall. The coefficient night be:

$p_{WY} = 0.6$

Suppose also that the river flow is inversely correlated with river quality. This would happen for example if there were discharges upstream. High concentrations would tend to occur when river flows were low because of the effect of dilution. The coefficient might be:

$p_{WX} = -0.4$

Suppose all the other correlation coefficients are zero. This gives the set:

$p_{WX} = -0.4$ $p_{WZ} = 0.0$
$p_{WY} = 0.6$ $p_{YZ} = 0.0$
$p_{XY} = 0.0$ $p_{XZ} = 0.0$

To impose these correlations on its data, MCARLO calculates:

$b_1 = p_{WX} = -0.4000$
$b_2 = \sqrt{(1 - b_1 b_1)} = 0.9165$

$c_1 = p_{WY} = 0.6$
$c_2 = (p_{XY} - b_1 c_1)/b_2$
$= (0.0 + 0.4 * 0.6) / 0.9165 = 0.2619$
$c_3 = \sqrt{(1 - c_1^2 - c_2^2)}$
$= \sqrt{(1 - 0.6^2 - 0.2619^2)}$
$= \sqrt{(1 - 0.36 - 0.06859)} = 0.7559$

$d_1 = p_{WZ} = 0.0$
$d_2 = (p_{YZ} - b_1 d_1)/b_2 = 0.0$
$d_3 = (p_{XZ} - c_1 d_1 - c_2 d_2)/c_3 = 0.0$
$d_4 = 1.0$

and uses these in Equation [7].

APPENDIX M.3 Calculation of Free Ammonia and the Depression of pH at the fish gill

1. The following sequence of calculations is used. Those in paragraphs 2 to 8 are for the carbonate equilibria in water, as used, for example, by the WRc for problems of water supply.

2. First set the value of a-bar in the Debye Huckel Equation:

abar = 6.0

Next calculate the constants, a and b, for the Debye Huckel Equation, using t, the temperature in degrees Centigrade:

a = 0.4989 + (t - 10) * 0.00078
b = 0.3264 + (t - 10) * 0.00018

3. Convert the alkalinity from mgl^{-1} to $molesl^{-1}$:

malk = 0.00002 * alk

and compute the Ionic Strength using the Total Dissolved Solids, tds:

i = 0.001 * tds / 40.0

4. Then compute the absolute temperature and its logarithm:

abtemp = t + 273.16
ablogt = $\log_{10}$ (abtemp)

5. The following equilibrium constants are used:

- Carbonate-bicarbonate:

$k_4 = 10.0^{(89.211 - 5081.1/abtemp - 33.341*ablogt)}$ [1]

- the overall dissociation of carbonic acid:

$k_5 = 10.0^{(118.52 - 5965.1/abtemp - 42.379*ablogt)}$ [2]

- the dissociation of water:

$k_w = 10.0^{(6.0846 - 4471.33/abtemp - 0.017053*abtemp)}$ [3]

6. The Activity of the hydrogen ion, a_h, is:

$a_h = 10.0^{(-pH)}$

And **Activity Coefficients** for mono-valent and divalent ions (f_1 and f_2) are:

$$f_1 = 10.0^{(-1.0 * a * \sqrt{i} / (1.0 + abar * b * \sqrt{i}))}$$
$$f_2 = 10.0^{(-4.0 * a * \sqrt{i} / (1.0 + abar * b * \sqrt{i}))}$$

7. Compute the Activity of the carbonate ion:

$$aCO_3 = (malk - k_w / (a_h * f_1) + a_h/f_1) / (a_h / (k_4 * f_1) + 2.0/f_2)$$

and the Activity of the bicarbonate ion:

$$aHCO_3 = a_h * aCO_3 / k_4$$

8. Calculate the Molality of carbon dioxide in the water:

$$mCO_2 = a_h * aHCO_3 / k_5$$

and work out the concentration of carbon dioxide in the water:

$$CO_2 = mCO_2 * 44.01 * 1000.0$$

(where 44.01 is the molecular weight of carbon dioxide)

9. Next add the extra carbon dioxide, xCO2, produced at the gill surface.

Assume that 70% of the Dissolved Oxygen in the water, DO mgl^{-1}, is converted to carbon dioxide at a linear rate along the gill. This gives the factors of 0.5 and 0.7 in the following equation. Also, assume a Respiratory Quotient of 0.8. Then:

$$xCO2 = 0.5 * 0.70 * 0.8 * (44.01/32) * DO \qquad [4]$$

where 44.01 is the molecular weight of carbon dioxide and 32 is the molecular weight of oxygen.

The original work of Alabaster and Lloyd used Equation [4] with a value of DO of about 8 mgl^{-1} and a conversion of Dissolved Oxygen to Carbon Dioxide set at 80%. This gave a value of 3.5 mgl^{-1} for the added Carbon Dioxide. This was equivalent, approximately, to setting the pH to 8 when field values of pH were bigger than this.

10. Compute the resulting pH at the gill surface:

$$pH\ gill = -\log_{10} (a_h * (CO_2 + xCO_2) / CO_2)$$

Compute the concentration of Free Ammonia at the gill from the Total Ammonia, TotAmm, the temperature, temp, and the pH at the gill, pH gill:

$$FreeAmm = TotAmm / (1.0 + 10.0^{(10.055 - (0.0324 * temp) - pHgill)}).$$

REFERENCES

For carbonate chemistry:

Ainsworth, R. 1979. The Calcium Carbonate - Carbon Dioxide - Water System: A Review of the Thermodynamic Data and the Calculation of Parameters which affect Corrosion Rates and Scale Deposition in Water Supplies. Water Research Centre. Report Number. LR1009.

Lloyd, R and Herbert, D.W.M. 1960. The Influence of Carbon Dioxide on the Toxicity of Un-ionised Ammonia to Rainbow Trout. Ann. Appl. Biol. 48, 399-404.