Environment Agency

North East Region

Guidelines for monitoring methodologies for water resources projects

The environment and water resources projects - Volume 2

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CONTENTS

1.0 INTRODUCTION

In its rôle as protector of the water environment, the Environment Agency requires significant water resources abstraction applications and schemes such as drought orders, drought permits, time limited licences, and river transfers to be environmentally assessed leading to the production of an environmental report or statement. This may not take the form of a formal Environmental Assessment, but is required to provide environmental information to support applications. (See Volume 1 - Guidance for Scoping and Environmental Assessment for Water Resources Projects in North East Region). This second volume concentrates on the environmental monitoring component of environmental assessments.

1.1 Need

Monitoring of the effects of schemes on the environment is an essential component of any environmental assessment carried out, in order to assess changes in the ecology of the affected watercourses, reduce the adverse effects of the impacts (mitigation), and provide information to be used when the impact has ceased (restoration). It provides the basis to ensuring sustainable use of the environment. There is a need for a guide on monitoring requirements, representing best practice which the North East Region of the Environment Agency expects others to follow.

1.2 Purpose

This document gives best practice guidance on a wide range of types of monitoring available for environmental assessment. Monitoring types span water quantity and chemical quality, habitat, plants, invertebrates, fish, birds, mammals, recreation and amenity, heritage, archaeology, navigation and photographic. Recommended standard methodologies and sources of information, frequency and reporting plus limitations of the methods and links are included.

The document is intended to act as a focus for the iterative process between the applicants (and consultants), and the Environment Agency, as the base document from which specific monitoring requirements will be identified for each scheme application.

It has been designed so that methods can easily be updated and/or added in the future.

1.3 The Role of the Agency and the Local Background

The Environment Agency is responsible for the protection of the water environment and has a duty to further conservation and maintain, improve and develop fisheries as well as balance the needs of the environment and water supply. In order to carry out such duties it requires environmental information collected by monitoring. The Environment Agency carries out its own monitoring for various statutory and non-statutory purposes

and requires others to do so for specific purposes.

The Environment Agency has advisory, operational and regulatory roles in environmental assessment. This means it can be a consultee for some projects, a developer for others as well as having powers to issue or refuse consents and licences for certain activities.

In the context of this document the Agency is only involved in the consenting, licensing and consultation process.

Under EC directive 85/337 developers are required to carry out formal Environmental Assessment for projects likely to have a significant impact upon the environment. The Town and Country Planning (Assessment of Environmental Effects) Regulations 1988 No.1199 (SI 1199) implements this directive and requires a formal Environmental Assessment if planning permission is to be granted. Permitted development and activities which do not require planning permission are exempt from SI 1199 but may be covered by other sets of regulations with similar requirements.

Formal Environmental Assessment will be undertaken following *Environmental Assessment: A Guide to the Procedures.* DOE, Welsh Office. HMSO 1989. It is recommended that such assessments must include monitoring undertaken to the guidelines laid down in this document.

Many projects are not covered by the legislation outlined above. In such cases the Environment Agency asks applicants to ensure good practice by following the environmental assessment process to evaluate the potential impacts of the proposed project.

All work undertaken should comply with Health and Safety legislation. The Environment Agency is not responsible for Health and Safety of abstractors or their contractors.

Permission is likely to be required from land owners for access for surveys and from land and fishery owners to remove samples or fish. Fishing by means other than a licensed rod and line will require permission from the Environment Agency.

It is recommended that Health & Safety Guidelines adopted by the Environment Agency are followed where these have been developed for particular monitoring equipment and techniques.

2.0 MONITORING TOPICS

2.1 Water Resources and Quality

2.1.1 Hydrology

Purpose	To provide data on flow, flow rates and depth in order to assess the impact of any changes to abstractions. In particular to compare the actual to predicted impact, provide data for water quality modelling and allow for the evaluation of links to establish the mechanism of any ecological impact
Methodology and Standards	Methodology and standards should follow BS 3680. In particular for spot gauging the requirements of *"Measurement of liquid flow in open channels" using current meter gauging - part 3 (a) Velocity Area methods ISO 748 (1979).* The gauging needs to be quality assured through the British Standards.
Frequency and Reporting	Dependent upon the severity and anticipated duration of the predicted impact on flow and levels, the availability of other relevant gauging station information, the needs of any particular hydrological model and the frequency of any linked ecological monitoring. For drought situations it is important to obtain a minimum of 6 readings during the event preferably from locations and at the same time as ecological monitoring. Photographic evidence of level changes should also be taken.
Limitations	At very low flow rates the accuracy of current gauging is reduced .
Links	Hydrology links to all other monitoring as the prime change in the river's characteristics caused by variations to abstraction conditions or drought.

2.1.2. Water Quality

Purpose	To monitor the impact on water quality of the anticipated changes to flow regime caused by variations to abstraction conditions or drought
Methodology and Standards	Site locations will depend upon many variables, and the use of existing Environment Agency sites is recommended as these will already have been targeted under the *"NRA programme for the monitoring of Water Quality"*. Additional sites will need to be evaluated using the *WRC 1989 "Handbook on the design and interpretation of monitoring programmes" J C Ellis*. The linking of the sites to ecological monitoring is recommended. Sample collection should be carried out in accordance with the *"National sampling procedures manual - Volume 25 - Quality management systems for environmental sampling"* using Samplers trained in these procedures and audited for compliance. Analysis of samples should be carried out in accordance with the Blue Book method for the relevant determinant, by a NAMAS accredited Lab. Where there is a need for rapid results, field analysis of a number of determinants can be carried out using test kits and meters. This is particularly useful for targeting sites and timing for placement of continuous monitors. **Acute effects :** Where acute water quality problems are predicted, mitigation measures will be required. These need to be targeted using continuous monitors with alarm facilities. A number of reliable instruments are available for use. These need to be maintained and calibrated in accordance with manufacturers' recommendations by qualified personnel.
Frequency and Reporting	This is dependent upon severity of the predicted impact on quality. The following impact criteria are given for guidance :- Minor - less than 10% within class - current Agency programme Moderate - remains within class - plus monthly at ecology sites for 12 months Significant - 1 class change - fortnightly at all sites for 24 months Severe - >1 class change - weekly at all sites for 36 months
Limitations	See Ellis (as detailed in methodology and standards section above).
Links	Water quality links to all other monitoring as the main secondary change in river characteristics after flow.

2.2 Ecology

2.2.1 Habitat

2.2.1a River Habitat Survey (RHS)

Purpose	River Habitat Survey is a system to classify rivers based on habitats of value to wildlife. It will establish an objective basis for assessing the state of river habitats. When fully developed and implemented, RHS will comprise four distinct but related outputs: 1. Standard field survey method. 2. A computerised database containing information from a national reference network of UK sites. 3. A classification of river types based on a predictive model of physical structure. 4. A scheme for assessing habitat quality. As such it is already being used for baseline data and for environmental appraisal.
Methodology and Standards	The standard methodology to be used is set out in *River Habitat Survey, Field Survey Guidance Manual, Environment Agency 1996*. It should be noted that only Environment Agency accredited surveyors should undertake survey work. A list of accredited surveyors is available from the Environment Agency.
Frequency and Reporting	Frequency is river specific and depends on how the work is linked with other surveys e.g. fisheries.
Limitations	Limited to rivers. By August 1996, the database will be operational; currently, interpretation and referencing are limited by this. Will not necessarily show acute problems, but will show longer term changes e.g. bankside vegetation structure.
Links	RHS links with river corridor, macro invertebrate and fisheries surveys. It also provides some geomorphological information in terms of flow type, substrate, bank material and also artificial features.

2.2.1b River Corridor Survey (RCS)

Purpose	A standard methodology to describe the conservation resource associated with rivers. River Corridor Survey (RCS) highlights important features which need protecting and identifies opportunities to rehabilitate and enhance degraded habitats. It can be used both as a reactive or strategic tool.
Methodology and Standards	The standard methodology to be used is detailed in *River Corridor Surveys: Methods and Procedures, Conservation Technical Handbook No. 1, National Rivers Authority, August 1992.* These procedures must be followed.
Frequency and Reporting	As a baseline survey, it should be carried out prior to any substantial changes, a repeat survey should then be undertaken within six months. The base line survey may only be used to identify important sections for further detailed works. Reporting should occur within a month of undertaking the work. This may be reduced to one week where short, critical sections need identifying for other work.
Limitations	Best use is for rivers, but can be adapted to other areas. This should only done following consultation. Adapted methodology has been used for lakes and barrier banks. No connections to acute problems.
Links	RCS links with river habitat, macro invertebrate and fisheries surveys. It can also be related to Phase I habitat surveys.

2.2.1c PHABSIM

Purpose	To identify how physical habitat changes with flow, as an input to the Instream Flow Incremental Methodology to provide the likely effect of those changes on flora and fauna and assist in identification of suitable minimum flows for negotiation.
Methodology and Standards	See Appendix 1, p37.
Frequency and Reporting	Monthly progress. Flow levels for cross section measurement to be agreed. PHABSIM to be available for running by all parties, as required.
Limitations	Measured variables may not limit flora and fauna. All rivers, but especially where shallow and not of low gradient.
Links	PHABSIM links with river habitat, macro invertebrate and fish population surveys plus angling usage. It may allow prediction of flows at which pools will become isolated.

2.2.1d Measurement of siltation of salmonid spawning areas of rivers.

Purpose	To determine the proportion of fine solids in gravel, which is correlated with successful egg incubation of lithophile fish. To obtain detailed information on gravel bed structure, bed samples must be collected, as far as possible, undisturbed. Grab samples or Surber samples are often deficient in the finer fractions of the deposit owing to either the subjective nature of the sampling procedure, or to elutriation during sampling. Samples are unorientated and any natural stratification that may be present is often destroyed during sampling. Freeze coring techniques do not have these drawbacks and vertically undisturbed sediments, including fractions, may be obtained.
Methodology and Standards	See Appendix 2, p.40.
Frequency and Reporting	Sites should be sampled in October, in order to just precede trout spawning. Site locations to be agreed with Environment Agency.
Limitations	Rivers only. No connection to acute problems.
Links	Measurement of siltation of salmonid spawning areas of rivers links with fish spawning assessment.

2.2.2 Plants

2.2.2a Algae - Nuisance planktonic algae

Purpose	To measure planktonic algal populations in order to assess the possible and actual occurrence of algal blooms which could lead to toxicity (e.g.. from blue-green algae or dinoflagellates) and water-quality problems (i.e. de-oxygenation), arising from reduced flows and consequent nutrient enrichment and increased retention times. It is particularly important to monitor blue-green algæ, where they are known to occur, or there is a high probability of them occurring, due to the risk they pose to the health of man and animals. In such cases immediate reporting is required. Algal bloom formation can lead to de-oxygenation and fish mortalities, as well as possible toxic effects on wildlife, farm animals, pets and humans engaged in water-contact sports.
Methodology and Standards	Methodology should follow '*The Enumeration of Algae, Estimation of Cell Volume and Use in Bioassay 1990*' ('Blue Book') to establish species composition and abundance, and to assess the potential for toxicity or de-oxygenation.
Frequency and Reporting	Surveys to be carried out on a daily, weekly or fortnightly basis over the period of the project, depending on the circumstances. The samples should be analysed and reported to the Environment Agency within 48 hours. Blue green algal blooms should be reported to the Environment Agency immediately because of the health risk.
Limitations	Appropriate use is largely restricted to still waters and slow -flowing rivers where planktonic algal populations can build up.
Links	Monitoring of nuisance planktonic algae links with water quality and Trophic Diatom Index monitoring.

2.2.2b Algae - Trophic Diatom Index

Purpose	To assess the ecological impact of nutrient enrichment from waste water treatment works during low flow conditions, where changes in benthic invertebrate communities do not show marked responses to organic enrichment.
Methodology	Methodology should follow *'The Trophic Diatom Index and Diatom Quality Index: A User's Manual', R & D Technical Report E2, M.G. Kelly., Environment Agency*; with a minimum of one upstream and one downstream sample.
Frequency and Reporting	Surveys should be carried out from spring to autumn (March to October) at two monthly intervals. Analyses and data to be provided to the Environment Agency as soon as is available and in no case later than two months after the last survey of the year.
Limitations	Availability of suitable substrate; water depth; river flow; confounding influences from herbicides and other toxic substances. Limited to shallow rivers with cobble or boulder substrates, in unshaded sections. No direct links to acute problems, although public complaints about aesthetic quality (black slimes and growths on the river bed) could be more readily answered.
Links	The Trophic Diatom Index links with macrophyte and macro-invertebrate surveys.

2.2.2c Macrophytes

Purpose	To assess the impact of low flows on the distribution, abundance and health of macrophytes (higher plants, mosses, liverworts, macro algae), especially with regard to their importance as habitat and shelter for invertebrates and fish. To monitor any shift in communities towards filamentous algae at the expense of water crowfoot and other ecologically valuable species.
Methodology	Methodology should follow *Methods for the Use of Aquatic Macrophytes for Assessing Water Quality - Standing Committee of Analysts 1985-6 ('Blue Book')*. Method B is advocated. Representative 500 m river lengths associated with the invertebrate sampling points should be surveyed and mapped. Alternatively, use the methods as given in *Methodology for the assessment of Freshwater Riverine Macrophytes for the purposes of the Urban Wastewater Treatment Directive* Version 2 May 1996 Environment Agency to produce a Mean Trophic Ranking for the macrophyte community
Frequency and Reporting	Surveys should be carried out at the start and end of the summer period (June-September). Analyses and data to be provided to the Environment Agency as soon as available and in no case later than two months after the last survey of the year.
Limitations	The method can be used in still or running waters. Surveying is limited primarily to shallow water unless divers are used to assess communities in deeper water. Year to year and seasonal variation may be large, obscuring long term trends.
Links	Macrophyte surveys link with river habitat, river corridor, macro-invertebrate and fisheries surveys.

2.2.3 Macro-invertebrates

2.2.3a Macro-invertebrate qualitative surveys of running waters

Purpose	To assess the effects on macro-invertebrate life, of low or reduced river flow resulting from the provision of a drought order or permit to reduce or cease a compensation flow to or increase abstraction from a river. To provide a general assessment of the macro-invertebrate community structure of the river and assess the effects caused by changes in water quality resulting from the reduced flows.
Methodology and Standards	Methodologies for surveys are to be based on the following publications:- *Procedure for collecting and analysing macro-invertebrate samples for RIVPACS*. (BT001) 1995. - Qualitative sampling and laboratory processing. (Sects. 4.2.;4.3.; 4.4.; 4.6.; 5.) Environment Agency *Procedure for collecting and analysing macro-invertebrate samples for GQA surveys.* (BT002) 1995. - AQC and Audit procedures. (Sects. 5.10.) Environment Agency Quality should be assured by means of an agreed AQC and Audit scheme to ensure quality of sampling, sorting and identification processes. Sites should be chosen following the River Habitat Survey of the reach of river under investigation. Control site(s) should be used, from within the catchment (if possible), which will not be affected by the drought orders/permits, to enable the effects of natural conditions to be determined. Sites should be chosen upstream and downstream of effluents or in stretches or river at risk of experiencing reduced water quality or habitat loss.
Frequency and Reporting	Generally, surveys are to be carried out during spring (March - May) and autumn (September to November), although there may be circumstances where more regular monitoring is required and this will be highlighted in discussions with the developer. Where suitable data have not been collected during 'normal' conditions prior to the commencement of drought orders/permits, it will be necessary to continue surveillance well after the return to normal conditions. This is necessary to monitor recovery and obtain a picture of normal conditions against which to compare the data obtained under the drought order restricted conditions. This may mean a surveillance programme of three to four years duration assuming there are no abnormal conditions in the years following the drought. Raw data and Biological Water Quality classifications according to Yorkshire Interpretative Index (YII) and the Environment Agency Biological GQA classification (when available) will be made available to the Environment Agency as soon as they are available and in no case later than two months following surveying. RIVPACS assessments will be made available by the Environment Agency on the receipt of the appropriate environmental and biological information.
Limitations	RIVPACS assessments are limited to river and stream samples. Rivers and streams of all sizes.
Links	Macro-invertebrate qualitative surveys of running waters link to water quality, hydrology and macrophyte monitoring, fish diet assessment and angling. There is no immediate connection to acute problems, but the results are to be used in the review of quality to assess the effectiveness of any mitigation measures and trigger requirement of additional mitigation.

2.2.3b Macro-invertebrate quantitative surveys of running waters

Purpose	To provide detailed information of the macro-invertebrate community structure, species abundance and biomass data for the river in order to assess population changes of individual species which may be attributable to the artificially produced conditions.
Methodology and Standards	The standing Committee of Analysts *Quantitative sampling for benthic macro-invertebrates in shallow waters* 1980. details equipment to be used. Surveys should be designed to provide the information required and provide for statistical validity of results. see J. Hellawell 1978. *Biological Surveillance of Rivers* (Sects. 3.5 and 3.6) Sorting methodology should follow that for Qualitative methodology (see above) with additional requirement for species identification and full enumeration of the sample. Quality of sampling, sorting and identification processes should be assured by means of an agreed AQC and Audit scheme. Sites should be chosen as representative, as determined by the RHS survey, of the reach of river under investigation. Control site(s) should be used from within the catchment (if possible) which will not be affected by the drought orders/permits, to enable the effects of natural conditions to be determined.
Frequency and Reporting	Sampling to be carried out as determined by the species/life cycle dependency under investigation. Where general population work is undertaken, spring (March to May) and autumn (September to November) should be sufficient. There may be a need to include a summer (June to August) series of sampling if the species compositions indicate that effects may be most enhanced during this period. Raw data will be made available immediately they become available and in no case longer than two months following the survey. Twinspan, Decorana and other agreed statistical methods to be used to establish changes in data between seasons and between years. These analyses will therefore not be immediately available. Initial analyses will be made available after a period of three consecutive seasons sampling, to enable decisions as to further sampling programmes to be made.
Limitations	Restricted to shallow waters and specific habitat types i.e. shallow streams and rivers with a relatively homogeneous substratum.
Links	Macro-invertebrate quantitative surveys of running waters link to water quality, hydrology and macrophyte monitoring, fish diet assessment and angling.

2.2.3c Macro-invertebrate surveys of still waters

Purpose	To assess the macro-invertebrate community of ponds, lakes, reservoirs and other standing waters in order to identify possible impacts of any changes in water level and quality.
Methodology and Standards	Dredging, sweeping, airlifting and core/grab techniques are approved for sampling macro-invertebrates from stillwaters. Methods for dredge, sweep and airlift sampling of flow flowing/deep rivers are described in the reference below. Sampling of stillwaters should be based on the relevant sections. The Environment Agency *Procedure for collecting and analysing macro-invertebrate samples for RIVPACS.* (BT001) 1995 Sections 4.2; 4.3; 4.6; 5.5.3; 5.5.4; 5.5.5;5.5.7; 5.7. The Environment Agency *Procedure for collecting and analysing macro-invertebrate samples for GQA surveys.* (BT002) 1995 AQC and audit procedures section 5.10 These documents were compiled for the sampling of deep slow flowing water habitats. References to RIVPACS can be ignored as the program is not applicable to still water samples. The level of identification required, *i.e.* family or species, will depend on the specific circumstances of the assessment, the likely impact and objective of the study and should be agreed with the Agency. Core/grab techniques should be based on the methodologies given in *Stillwater Benthos Methodologies.* Environment Agency, Anglian Region, 1996. Quality of sampling, sorting and identification processes should be assured by means of an agreed AQC and Audit scheme.
Frequency and Reporting	Because data may not have been collected during 'normal' conditions prior to the commencement of drought orders/permits, it is necessary to continue surveillance well after the return to normal conditions. This is necessary to monitor recovery and obtain a picture of normal conditions against which to compare the data obtained under the drought order restricted conditions. General assessments require a minimum of two sampling occasions per year separated by a minimum period of three months. Where drawdown is affecting important marginal habitats, more frequent sampling may be necessary to adequately monitor the impact on the invertebrate fauna. Raw data should be made available as soon as possible and in no case later than two months following a survey. Data from Quality Control and Audit schemes should also be presented.
Limitations	Dredging, airlifting and sweeping methods are most appropriate for smaller water bodies or marginal areas of large lakes and reservoirs. Core/grab methods from boats are best suited to sampling the benthos of deeper/larger lakes.
Links	Macro-invertebrate surveys of stillwaters links to water quality, hydrology, macrophyte and algal monitoring.

2.2.3d Surveys for rare or protected macro-invertebrate species

Purpose	To provide detailed information on the distribution and abundance of rare or protected invertebrate species in aquatic habitats which could be affected by reduced flows or lowered water levels.
Methodology and Standards	The Biodiversity steering group has identified a list of globally threatened/declining species, of which the following invertebrates occur in North East region: *Austropotamobius pallipes* — White-clawed crayfish *Margaritifera margaritifera* — Freshwater pearl mussel *Myxas glutinosa* — Glutinous snail *Vertigo angustior* — a snail *Vertigo genesii* — a snail *Vertigo geyeri* — a snail Where the above species occur within the study area, the corresponding Biodiversity Action Plan for that species should be consulted. Other rare invertebrate species are listed in the International Red Data Book. In addition, *Austropotamobius pallipes* and *Margaritifera margaritifera* are protected under Schedule 5 of the Wildlife and Countryside Act 1981. Consequently, a licence is required from English Nature for sampling and all surveyed animals should be returned unharmed. Surveys should be carried out wherever rare or protected invertebrate species, including local or national rarities, are known or suspected to exist. In general, suitable methods can be selected from those described in the macro-invertebrate survey methods section of this manual; species identification will be essential. Where surveys for *Austropotamobius pallipes* are planned in stillwaters, the use of traps may be the most appropriate sampling technique. As such traps constitute 'fixed engines' the details of such surveys must be agreed with the Environment Agency as well as English Nature.
Frequency and Reporting	Where rare or endangered species are found this should be communicated to the Agency and English Nature immediately. It is probable that a comprehensive survey to establish distribution and abundance will then be required, with subsequent monitoring of significant populations at least twice yearly. Data should be reported to the Agency as soon as practicable and in no event later than two months after completion of each survey.
Limitations	A suitable assessment is dependant on initial detection or knowledge of the presence of rare or endangered invertebrate species.
Links	Surveys for rare or protected macro-invertebrate species link to water quality, hydrology, river habitat and corridor, macrophytes, algae and macro-invertebrate monitoring. There may be connections to acute problems such as the potential loss of colonies of rare or endangered invertebrates.

2.2.4 Fish

2.2.4a. Fish population surveys for rivers less than 15 metres in width

Purpose	To assess fish stocks in shallow rivers less than 15 metres in width in order to identify possible impacts.
Methodology and Standards	The following methods should be used for guidance only. Specific requirements related to site and scheme must be agreed with the Environment Agency prior to commencement of monitoring. 1. Control sites should be established to quantify what degree the identified changes are attributable to reductions in flow due to drought orders/ permits, as opposed to natural flow variation. 2. River Habitat Survey data (Section 3.1) should be used to identify the percentage of a particular type of habitat within a given section of river. The Environment Agency River Habitat Survey Manual should be used for this purpose. Number and location of survey sites to be based on this information to ensure representative coverage of habitats. 3. Quantitative fish stock surveys to be carried out on all sections of river/stream less than 15 metres in width using the following methods/equipment: - pulsed d.c. electro-fishing equipment (50 or 100 kHz); - 50 metre long sections fished by wading upstream; - stop nets at top and bottom of section (physical obstruction e.g. weir may be used to restrict movement); - sections less than 5 metres wide - single anode; - sections between 5 and 10 metres wide - 2 anodes; - sections between 10 and 15 metres wide - 3 anodes. Safe working procedures are set out in the Environment Agency *Code of Practice for Safety in Electric Fishing Operations.* Further details of methods are in: *HMSO (1988) Standing Committee of Analysts. Methods for sampling fish populations in shallow rivers and streams. 1983. ISBN 01 752085 3* 4. Depletion sampling using maximum weighted likelihood statistical estimation for numbers in populations.
Frequency and Reporting	Annual surveys to demonstrate stock changes. Quarterly surveys may be required to demonstrate seasonal movements. Raw data to be available to the Environment Agency within one month of field work. Full report required within six months of finish of field work. Information provided should include all data required to produce Absolute and Relative Classifications at Level 1 or Level 2 of the NRA National Fisheries Classification Scheme. *The NRA National Fisheries Classification Scheme. A Guide for Users.* R&D Note 206. NRA (1994)
Limitations	Mortalities due to use of pulsed d.c. under certain environmental conditions. Use smooth d.c. as an alternative. Underestimation of population size due to reducing susceptibility of fish to capture on subsequent runs.
Links	Fish population surveys for rivers less than 15 metres in width link to River Habitat Survey for site choice. PHABSIM for effects of flow variation. Biological monitoring and water quality monitoring to be carried out at the same site. Flow variations to be recorded together with any other observed factors which may influence results.

2.2.4b Fish population surveys for shallow rivers more than 15 metres in width

Purpose	To assess fish stocks in shallow rivers more than 15 metres in width in order to identify possible impacts.
Methodology and Standards	The following methods should be used for guidance only. Specific requirements related to site and scheme must be agreed with the Environment Agency prior to commencement of monitoring. 1. Control sites should be established to quantify what degree the identified changes are attributable to reductions in flow due to drought orders/ permits, as opposed to natural flow variation. 2. River habitat survey data (Section 3.1) should be used to identify the percentage of a particular type of habitat within a given section of river. The River Habitat Survey (RHS) Manual should be used for this purpose. Number and location of survey sites to be based on this information to ensure representative coverage of habitats. Other factors to be used in site selection: i. Angler activity and distribution (Section 8.6) ii. Effects of seasonal aggregation (concentrations of fish in weir pools pre- and post-spawning) 3. Qualitative fish stock surveys to be carried out at selected sites using the following protocol: - pulsed d.c. electro-fishing equipment (50 or 100 kHz); - 2 or more anodes; - sections fished by wading or from a boat working upstream; - 1 gill net to be set (50 metres, multi-mesh) with the flow in deeper water in the site, during electro-fishing operations; Safe working procedures are set out in the Environment Agency *Code of Practice for Safety in Electric Fishing Operations.*
Frequency and Reporting	Annual surveys to demonstrate overall stock changes. More frequent surveys may be required to demonstrate fish population movements. Raw data to be available to the Environment Agency within one month of field work. Full report required within six months of finish of field work. Information provided should include all data required to produce Absolute and Relative Classifications at Level 1 or Level 2 of the NRA National Fisheries Classification Scheme: *The NRA National Fisheries Classification Scheme. A Guide for Users.* R&D Note 206. NRA (1994)
Limitations	Mortalities due to use of pulsed d.c. under certain environmental conditions. Use smooth d.c. as an alternative. Underestimation of population size due to reducing susceptibility of fish to capture on subsequent runs.
Links	Fish population surveys for rivers more than 15 metres in width link to River Habitat Survey for site choice. PHABSIM for effects of flow variation. Biological monitoring and water quality monitoring to be carried out at the same site. Flows variations to be recorded together with any other observed factors which may influence results.

2.2.4c Fish population surveys for deep rivers more than 15 metres in width

Purpose	To assess fish stocks in deep rivers more than 15 metres in width in order to identify possible impacts.
Methodology and Standards	*Electric fishing in deep rivers. NRA R& D Note 303* provides further details of methods. 1. Boom boats using multiple anode boom arrays, pulsed d.c. (50 or 100 kHz), 4-7.5 kVA generators. Used in association with depletion sampling, calibrated effort, relative assessment or mark-recapture techniques for statistical estimation. 2. Hydroacoustics Equipment - Simrad or HTI (Biosonics dual beam Models 102 or 105 also acceptable) with suitable transducer selected to give a beam angle which fills the most volume at the depths and ranges being examined. *Hydroacoustic methods of fish survey.* NRA R&D Note 196 gives background to the method. Target strength to be calibrated by reference to a standard copper sphere Transducer mounting at least 1m in front of the boat at a depth of 50-70cm adjustable angle. Boat should give a stable platform with a maximum 5kph ground speed. Minimum ping rate 5 per sec., pulse width 0.3, -50dB target threshold, minimum signal to noise ratio of 3:1. Surveys to be undertaken at night (1 hour after sunset to 1 hour before dawn) between June and September. Side-scanning to occur from both banks Environmental conditions should be recorded and reported - air and water temperatures, cloud cover, moon phase, flow and turbidity (Secchi disc). 3. Seine netting. The 'wrap-around' technique, as described in Coles, T.F., Wortley, J.S., & Noble, P. (1985). *Survey methodology for fish population assessment within Anglian Water.* J. Fish Biol. 27, (Supplement A), 175-186.
Frequency and Reporting	Annual surveys to demonstrate overall stock changes. More frequent surveys may be required to demonstrate fish population movements. Raw data to be available to the Environment Agency within one month of field work. Full report required within six months of finish of field work. Information provided should include all data required to produce Absolute and Relative Classifications at Level 1 or Level 2 of the NRA National Fisheries Classification Scheme. *The NRA National Fisheries Classification Scheme. A Guide for Users.* R&D Note 206. NRA (1994) Hydroacoustics - fish densities should be reported for targets >-50dB as number per 1000 cubic metres beyond a minimum range of 2m. Bottom echoes should be manually excluded and single targets counted at 40log R by discriminating on basis of 0.8-1.4 of returning pulse length. Fish size distribution tone reported by conversion from target strengths.
Limitations	1. Boom boat fishing restricted by high conductivity, occurrence of suitable boat launching sites, dense macrophyte cover, water too shallow for boat draught, high water velocities. 2. Hydroacoustics - rivers of minimum width 25m and minimum depth 2m - limited by requirement for verification of target identification, air entrainment (boats and weirs), suitable fish behaviour as affected by light, temperature, flow, turbidity. 3. Seine netting is restricted by uneven substratum, dense macrophyte cover and high water velocities.
Links	Biological monitoring and water quality monitoring to be carried out at the same site. Flows variations to be recorded together with any other observed factors which may influence results.

2.2.4d Coarse fish fry surveys

Purpose	Assessment of species composition, relative abundance and growth rates of coarse fish fry stocks
Methodology and Standards	1. Fry seine. 20m x 2m x 2.5mm knotless mesh employed by wading around shallow bays. Three hauls. Entire catch preserved in 10% neutral buffered formalin. Soak overnight in water and sort in a fume cupboard into species. For each site, entire numbers of each species recorded and up to 100 of each species measured and length recorded. Type specimens probably required for confirmation of identifications. 2. Point source abundance. Anode ring mounted on a telescopic pole and powered with pulsed d.c. from a battery source. Up to 10 point samples are taken over a 25m length in marginal areas where fry congregate. 3. Breeder traps.
Frequency and Reporting	Survey early September for routine surveys, otherwise discuss with Environment Agency. Raw data to be available to the Environment Agency within one month of field work. Full report required within six months of finish of field work.
Limitations	Identification of small fry may require type specimens. Discontinuous, contagious distributions allow no easy quantitative sampling methods. Breeder traps are too selective in relation to species, season and habitat to be useful in most circumstances.
Links	Coarse fish fry surveys link to water quality, especially temperature data, fish population surveys and fish health assessment.

2.2.4e. Fish diet assessment

Purpose	To assess diet changes in fish populations caused by the scheme.
Methodology and Standards	General methods are given in: *Ricker (1971) Methods for the Assessment of Fish Production in Freshwaters. IBP Handbook No. 3, Blackwell.* Short term sampling may be necessary to detect diurnal variation.
Frequency and Reporting	Samples to be collected and processed every 3 months, with reporting monthly.
Limitations	May require large samples of fish due to data variability. Identification of dietary items may require type specimens. Non-destructive sampling methods are difficult for fish without true stomachs. Digestion of gut contents.
Links	Fish diet assessment links with macro-invertebrates and fish health assessment. May detect acute problems such as food availability, behavioural changes.

2.2.4f. Fish spawning assessment

Purpose	To assess spawning activities of fish populations.
Methodology and Standards	Visual assessment of spawning activity and location. Redd counts of salmonids Post-mortem examination of dead fish (gonad stage). Egg incubation in artificial media (salmonids) - stand pipes.
Frequency and Reporting	Regular patrols in spawning periods, with monthly reports unless specific problems detected (e.g. lack of access). Raw data to be available to the Environment Agency within one month of field work. Full report required within six months of finish of field work.
Limitations	Anecdotal information, lack of historical data, observational problems.
Links	Fish spawning assessment links with river habitat surveys, fish population surveys, coarse fish fry surveys, fish health assessment and angling censuses.

2.2.4g. Fish health assessment

Purpose	To assess changes in fish health as a result of the scheme, including gross pathology, parasitology, bacteriology and virology.
Methodology and Standards	General methods for the routine examination of fish are given in *Procedures for the examination of fish prior to transfer.* Environment Agency. Other methods - visual inspection for ectoparasites, gross pathology, photographs.
Frequency and Reporting	A minimum of one sample should be taken before and after commencement of the impact. However, due to seasonal variation in pathogen abundance and effect, several samples may be required.
Limitations	Natural variations in pathology.
Links	Fish health assessment links with fish population surveys and fish diet assessment (if fish are processed rapidly). It may detect acute disease outbreaks and consequent mortalities

2.2.4h Fish movement and behaviour

Purpose	To assess changes in fish movement and behaviour.
Methodology and Standards	Tracking, PIT tagging, marking, visual observation, hydroacoustics, fish counters. Tracking methods are described in *Description of NRA Tracking Studies, R&D Note 33*
Frequency and Reporting	Dependent on method - refer to Environment Agency.
Limitations	Fish identification, equipment, conductivity, depth, turbidity, flow.
Links	Fish movement and behaviour links with fish counters.

2.2.4i. Fish counters

Purpose	To assess numbers and species of migratory fish passing a fixed point in the river.
Methodology and Standards	Use of conductivity based or acoustic counters, cameras, tagged fish. For standard methods relating to conductivity counters refer to *Environment Agency R&D Note 382, Design and use of fish counters.* (Due for publication August 1996) Hydroacoustic counters are being evaluated as a research project No. 486, Assessing salmon stocks using a hydroacoustic counter. Contact Peter Gough, Welsh Region, Environment Agency for further details of method.
Frequency and Reporting	Separate validation report. Continuous assessment, with access available to Environment Agency staff. Weekly summaries of numbers and species.
Limitations	General - species identification, interference by other species, objects, turbidity, validation. For conductivity types - site characteristics e.g. flow velocities, depth. For hydroacoustic - site characteristics e.g. depth, bed profile, substratum composition. Applies to rivers only.
Links	Fish counters link with water quality and fish movement and behaviour.

2.2.4j. Fish entrainment

Purpose	To assess numbers, species, and sizes of fish entrained at water intake structures and numbers and mortality of fish impinged on screens. It may show whether or not large numbers of fish are being entrained and undesirably transferred.
Methodology and Standards	For impingement - collect dead/moribund fish from collection device. For entrainment - need to organise collection method- eg. trawl, plankton nets. A louvre screen trap is described in *Diversion and entrapment of fish at water intakes and outfalls*. R&D Report No. 1. NRA (1992). Hydroacoustics. Night time operation of pumps is likely to give higher entrainment rates due to loss of visual clues for holding station.
Frequency and Reporting	Weekly data collection, collated and reported monthly to Environment Agency. Significant numbers (>100, depending on species) of fish entrained to be reported within 1 working day. Fish densities to be reported in terms of flow rates.
Limitations	Identification of small/damaged fish, sampling, holding facilities. Clogging of nets by debris.
Links	Fish entrainment links to fish population surveys and fish spawning assessment .

2.2.5 Birds

Purpose	To establish the likely impact of low flow/abstractions/transfers upon bird populations and to ensure the protection of species scheduled under UK legislation, EC Directives and international conventions.
Methodology and Standards	Methods as prescribed by the British Trust for Ornithology - e.g. River Bird Surveys, Wildfowl and Wader Counts. Those involved in monitoring should be recognised as competent by BTO. Previous BTO surveys should be used as a base line for further studies. Guidance on methodology should also be sought from English Nature and the Royal Society for the Protection of Birds.
Frequency and Reporting	Survey timings will be seasonal, according to whether breeding, wintering or migrating birds are being monitored. Reports should be available within six months of the last survey fieldwork. Results of surveys should be discussed with and analysed by the BTO and if a designated site is involved (e.g. SSSI, SPA) with English Nature. It is advisable to involve the RSPB in these discussions.
Limitations	Various forms of monitoring are restricted to particular seasons. River Bird Surveys and Common Bird Census work can only be carried out during the breeding season (April - June), Wildfowl Counts only in winter (October - March). Numerous factors can affect bird population numbers and it is often difficult to isolate and attribute particular causes of observed change in populations.
Links	Bird surveys link with river habitat, corridor, macro-invertebrate and fish population surveys.

2.2.6. Mammals

Purpose	To establish likely impact of low flows/abstractions/ water transfers upon mammal populations and to ensure the protection of the species scheduled under UK legislation, EC Directives or international convention.
Methodology and Standards	Methods prescribed by national bodies - advice must be sought from English Nature. In the case of protected species (e.g. otter, bats, etc) surveyors must be licensed by English Nature. Guidance should also be sought from County Wildlife Trusts, local species protection groups eg. bat groups and other local and national experts. Species perceived as being at particular risk are otter, water vole, and badger (in the case of pipelines).
Frequency and Reporting	Regular liaison with English Nature, Wildlife Trust, (Yorkshire and Durham) Otter Projects and with Environment Agency conservation staff. Reports should be compiled covering particular proposals and an annual report on the overall results of the monitoring programme.
Limitations	Mammals can be very wide ranging and it can be difficult to define the parameters of all their habitat requirements. Disturbance - even whilst monitoring can constitute an offence in certain cases. River/weather conditions can have a major effect upon survey/monitoring results.
Links	Mammal monitoring links with water quality, hydrology, river habitat and corridor, macrophytes, macro-invertebrates and fish population surveys.

2.3 Human Aspects

2.3.1 Recreation

2.3.1a Angler catch data

Purpose	To assess changes in fish populations, year-class strengths, species composition, catch per unit effort related to flow changes.
Methodology and Standards	Use of census clerks (employed and trained) at agreed locations, to monitor pleasure fishing, match fishing. Use of log books.
Frequency and Reporting	Angler catch data should be collected weekly, collated and reported on a monthly basis to the Environment Agency. Data should include numbers fishing, times fished, species and sizes of fish caught, total weight caught and proportion of anglers without catch.
Limitations	Training required. Large data set required for robust analysis. All water bodies.
Links	Angler catch data links to macrophyte and fish population surveys, fish health assessment, fish movement and behaviour, plus angling distribution/activity. The opportunity should be taken to collect data on fish health (gross indications) and condition

2.3.1b Angling distribution/activity

Purpose	To assess the level of angling activity in terms of locations fished, for how long, and identify any factors limiting fishing e.g. low water-levels, physical problems e.g. weed build up on lines.
Methodology and Standards	Patrols of affected areas, with interviews of anglers. Log books, catch return system. Aerial assessment where practicable. Pollock, K.H., Jones C.M. and Brown, T.L. (1994). *Angler survey methods and their application in fisheries management.* American Fisheries Society Special Publication 25. gives details of a variety of methods.
Frequency and Reporting	Weekly patrols, with monthly reports. Notification of significant problems to Environment Agency within 1 working day.
Limitations	Yearly variation. Distribution not directly related to stocking. Applies to all water bodies. (but mainly rivers).
Links	Angler catch data. May assist in identification of reduction in angling effort and/or available fishing areas

2.3.2 Aesthetics and Landscape

Purpose	To place the impact of the project work in perspective for the surrounding landscape. To provide a detailed measure of the change in landscape value which may arise from the project.
Methodology and Standards	National Rivers Authority River Landscape Assessment Methods and Procedures, Conservational Technical Handbook No 2, 1993. Macro river landscape. Micro river landscape.
Frequency and Reporting	Before and after works. Further monitoring 5, 10 years after completion.
Limitations	Method needs to be applied at the appropriate scale as explained in the National Rivers Authority handbook. Needs to be completed in good / reasonable visibility. Avoid short days and bad weather during winter.
Links	Landscape assessment links to river habitat and corridor monitoring and also fixed point photography, geomorphology, topography or morphology studies.

2.3.3. Archaeology and heritage

Purpose	To protect our heritage in the form of archaeological sites and remains, potential sources of archaeological data (e.g. fossil soil deposits), potential landscapes (e.g. listed battlefields, registered parks and gardens, AONB, etc.) and historic landscapes in general.
Methodology and Standards	To be determined in consultation with County/Unitary Authority Archaeologists. Pipeline routes should be planned ahead and archaeologists/planners consulted prior to the start of work.
Frequency and Reporting	As above. Archaeological/heritage work should be coordinated centrally. Contract archaeologists should be employed with each pipe laying team.
Limitations	A large proportion of archaeological remains have not yet been discovered, and may not be recognised by a non-expert. Contract archaeologists should be employed on each pipeline project and archaeological heritage work should be coordinated centrally.
Links	Archaeology/heritage monitoring links with aesthetics and landscapes.

2.3.4 Navigation

Purpose	To gauge commercial and amenity uses of navigation. Commercial uses are best professionally assessed through essential liaison with the navigation authority (often British Waterways). Water resources/levels to sustain navigation, commercial or leisure, may be critical
Methodology and Standards	Liaise with British Waterways or other appropriate navigation authority/owner for usage information and influence the (whole) viability of a waterway for navigation. Differentation between waterway categories - commercial/cruising/remainder (affects resource and maintenance priorities).
Frequency and Reporting	Amenity/recreational navigation is seasonal, therefore data collection should cover a year to put usage in perspective. Demands of commercial traffic may persist throughout the year - but there will be a seasonal (mid/late summer) peak in leisure use when introduction of water saving measures/shared use of locks etc must be considered.
Limitations	Navigation is variable, influenced by tourism, popularity of the navigation.
Links	Navigation links to hydrology, macrophyte and recreation monitoring.

2.3.5 Photographic

Purpose	Fixed Point photography, to give base line information in the form of fixed point data to monitor later change, to give a visual record of extreme conditions . This can be permanently used to record changes in water levels and wetted areas of rivers and streams which occur as a result of reduced flows. A record can also be obtained of the effects on in stream and marginal vegetation
Methodology and Standards	Two fixed points must be established which should be clearly marked (example crosses painted on to large stones One point marks the position of the photographer when taking the picture, the second is the area at which the camera should be pointed.
Frequency and Reporting	Can be undertaken on almost any frequency depending upon predicted changes.
Limitations	Any water course, high flow conditions may obliterate sites.
Links	Fixed Point Photography can link to flow data recording, algae and macrophyte monitoring, plus landscape assessment. It can also link to the aesthetic perceptions of water courses.

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4.0 GLOSSARY

AONB	Area of Outstanding Natural Beauty
AQC	Analytical Quality Control
BS	British Standards
BTO	British Trust for Ornithology
Benthic	Living on the river/lake bed
Benthos	Plant and animal life of the river/lake bed
GQA	General Quality Assessment
IFIM	Instream Flow Incremental Methodology
ISO	International Organisation for Standardisation
Lithophile	Growing, living or sheltering amongst stones
Macrophyte	Plants individually visible to the naked eye
NAMAS	National Measurement Accreditation Service
NRA	National Rivers Authority
PHABSIM	Physical HABitat SIMulation
PIT Tagging	Passive Integrated Transponder
RCS	River Corridor Survey
RHS	River Habitat Survey
RIVPACS	River InVertebrate Prediction And Classification System
RSPB	Royal Society for the Protection of Birds
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WRC	Water Research Centre

Appendix 1

Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation (PHABSIM)

IFIM was designed to quantify environmental impacts of changing flows. It can consist of a series of models based on: macrohabitat, such as temperature and dissolved oxygen, usually one dimensional; microhabitat, such as depth/velocity distributions in association with substrate material and cover in small cells, two dimensional; and time series of the total amount of usable habitat present in aggregate over the specified length of stream.

Existing flow controls over abstractions are based on fixed minimum flow figures with little data basis against which to judge effects of changes in flow. Adverse effects of flow reductions are likely to be related to the period for which they occur, season, weather conditions, physical habitat etc. The existing minimum flows are almost always less than the optimal or pristine habitat condition. As minimum flow requirements are reduced in response to drought conditions, it becomes more and more important that scientific data on damage likely to result is available as part of the bargaining process. Standard methods, such as those based on a percentage of mean annual flows, do not give enough information about the consequences of reductions to allow an informed compromise. Techniques are required that show the relation between the amount of habitat and stream flow.

Techniques such as Habscore, RIVPACS, Fisheries Classification and Habitat Quality Index allow comparison of measures of the biota against those expected on the basis of habitat conditions, usually recorded under 'normal' flows. Biota of poorer than expected quality may be related to adverse physical conditions under low flows, but could be related to other factors. Under very low flow conditions, for example, a high population density of trout may be found that is at the upper end of the range expected on the basis of cover and depth measured at very low flows by Habscore techniques. Fish will be concentrated due to the reduction in wetted perimeter and cover suitable for larger trout will also be likely to be reduced.

A second group of techniques link channel hydraulics with known elements of physical conditions preferred by biota. The main difference is that variations in flow can be related to changes in physical habitat and thus to characteristics of the biota, such as recruitment, if physical habitat is a controlling influence. PHABSIM is an example of a model relating channel hydraulics to flow. Many people confuse IFIM with PHABSIM. Whereas IFIM is a general problem-solving approach employing systems analysis techniques, PHABSIM is a specific model designed to calculate an index to the amount of microhabitat available to different life stages at different flow levels.

PHABSIM requires the collection of field data on stream cross sections and habitat features, hydraulic simulation to evaluate habitat variables at different flows, and species suitability criteria to calculate stream characteristics with available habitat at varying flows.

There are two frequently challenged features of PHABSIM. The first is the necessity to erect suitability response curves for life stages of species and the second to analyse habitat species by species. Site specific collection and verification of field data is the preferred option for the first of these, but expert opinion has also been used. Analysis for individual species ignores species interactions that may affect habitat selection. PHABSIM has also been criticised because it contains only a few variables, namely depth, velocity and channel index (usually a combination of substrate material and cover). However, in studies of stream-dwelling animals, these variables have consistently been found to be important determinants of species distributions and abundance. It remains the only system available that allows the prediction of possible impacts arising from changes in discharge regime.

Methodology.

1. Using maps and aerial photographs/video recordings, identify the main reaches, including tributaries, to be examined on the basis of control reaches and those most affected by flow changes, isolation of populations of flora and fauna, plus differences between the populations of different reaches.
2. Estimate the proportions of those chosen reaches containing particular types of physical instream habitat, e.g. riffle and pool, run, impounded, bed rock.
3. Collect RHS data so as to ensure all major habitat types are covered and totals can be computed for the entire reaches.
4. PHABSIM surveys on all RHS habitat types

PHABSIM as per the PHABSIM software available from the Institute of Hydrology. Conducted under at least three different flows, including one as low as possible.

(i) Head pins established for each transect and their elevations surveyed relative to a fixed datum level.
(ii) Inter-transect distances measured on the left and right banks and as triangulations.
(iii) Bed profiles surveyed at each transect using >20 points evenly spaced across each transect.
(iv) Observations made on the dominant substrate in the immediate vicinity of each data point, using the Wentworth scale for particle size classification.
(v) Mean column velocity measured with a current meter at the approved point in the water column related to depth.
(vi) Water surface elevations surveyed relative to the fixed head pins at each transect (average of 3 points across stream).
(vii) Steps (v) and (vi) repeated at agreed flows.

5. Ensure that fish population surveys are conducted at PHABSIM survey sites, in order to relate fish distribution and abundance to habitat variables.
6. Choose suitability index curves for life stages of flora and fauna in conjunction with EA.
7. Compute weighted usable areas versus discharge. Compute time series for the relevant period.

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Appendix 2

Siltation of salmonid spawning areas of rivers.

Methodology.

To obtain the freeze cores a 25mm diameter copper pipe is inserted in the river bed to a depth of about 400mm. Where compact sediment makes insertion of the tube difficult, a solid metal rod is driven into the bed to make a pilot hole for the tube. Once the tube is in place, 2 litres of liquid nitrogen is gradually poured into the tube over a 5-10 minute period. The tube with the frozen attached sediment is then withdrawn and left on a tray to thaw. The tray is partitioned transversely into 100mm sections in order to permit depth stratification of the sample. Sediment samples from, the different depth zones are then placed separately in polythene bags.
(Apparatus available from Duncan and Associates, £339 (spiles), lifting frame/block £700. Contact - Peter Harding.)

The freeze cores often do not sample the various zones of sediment evenly; the upper sections of the core frequently having a smaller diameter than the middle, because of the high permeability of the superficial sediments allowing water to flow through the upper layers and thus prevent complete freezing of the sediment. In order to reduce the problem of incomplete freezing, a large diameter tube (460 mm) is driven into the top 150 mm of the gravel prior to insertion of the core tube. This effectively reduces the intra-gravel flow and allows better freezing of the upper sediment layer.

5 samples should be taken along a random transect. Cores should be taken randomly at each site with the extreme margins of the river being avoided. Site sketch maps of the exact location of the cores should be made. Measurements of core length and the depth where fine sediment infiltration of the gravel began should also be made.

Sediment analysis is to be carried out by washing the gravel through a succession of sieves. Sieve sizes used are 64mm, 36mm, 17mm, 8mm, 4mm, 2mm, 1mm, 0.5mm, 0.25mm, 0.125mm and 0.045mm. Wet sieving is to be used in order that very fine the very fine particle fractions do not adhere to the larger particle fractions during drying and hence not be separable on analysis. The liquid runoff from this wet sieving process is retained and the volume measured. A proportion of this suspension is to be suction filtered through Whatman 541 filter paper. All size fractions of sediment are then oven dried (80°C for 48 hours), and weighed. The weight of the sediment on the filter paper is multiplied proportionally to obtain the total weight of fine (<0.045mm) sediment.

In order to reduce the number of variable for consideration, and to permit comparison of data with other published work, results are to be analysed both in the form of median percentage weight of individual fractions of sediment (% Xmm), and cumulative median percentage weight of sediment below a particular size category (% < Xmm). It should be noted that in the following discussions of particle sizes, when a particular fraction is referred to as, for example, %8 mm,

that it represents the range of particle sizes between the adjacent sieve sizes that was retained by the 8mm sieve, i.e. for a size of 8mm the true range of sizes are particles between 16.9mm and 8mm. Where, however, sediment is referred to as, for example, %<8mm, it refers to sediment below that retained by the 8mm sieve i.e. 7.9mm to and including the filter paper fraction.
Median values are used in preference to mean values as the data are often not normally distributed, and the use of the median would diminish the influence of data outliers.
Sand indices (Peterson & Metcalfe 1981) should also be calculated using particle size categories of <2.0mm to >0.5mm and <0.5mm to 0.045mm for the coarse and fine sand respectively.
Care should be taken with transport and decanting of liquid nitrogen; and lifting blocks under very cold conditions.