Mean Trophic Rank: A User's Manual



Research and Development
Technical Report
E38

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Mean Trophic Rank: A User's Manual

R&D Technical Report E38

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Statement of Use
This report sets out procedural guidance on how to carry out Mean Trophic Rank (MTR) macrophyte surveys to assess the trophic status of rivers, and on the use of the method for the purposes of the EC Urban Waste Water Treatment Directive. The methodology can also be used for other applications. The guidance supersedes and replaces earlier, internal guidance issued to Environment Agency staff. It is intended as 'best practice' standard methodology for all MTR surveys and is applicable throughout the UK.

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GLOSSARY

Audit survey	Repeat survey undertaken for quality assurance purposes.
CCW	Countryside Council for Wales.
Channel area	The part of the river channel where macrophytes are seen submerged or partly submerged at low flow levels. At the sides of the channel this includes all macrophytes attached or rooted on parts of the substrata which are likely to be submerged for more than 85% of the year.
Comparability	A measure of confidence in the physical comparability of a pair of sites based upon the similarity of width, depth, substrata, habitat, shading, water clarity and bed stability.
CVS	Cover Value Score. The score allocated to a species resulting from the multiplication of the *Species Trophic Rank* and the *Species Cover Value.*
DoE	The Department of the Environment.
d/s	Downstream.
EN	English Nature.
DQI	The Diatom Quality Index. A transformation of the *Trophic Diatom Index* for use when comparing TDI and MTR results.
Highlighted species	Refers to a plant species within MTR which is believed to be a particularly reliable indicator of trophic status.
IFE	The Institute of Freshwater Ecology.
IRTU	Industrial Research & Technology Unit, Northern Ireland.
LEAP	Local Environment Agency Plan.
Macrophyte	Larger alga or higher aquatic plant (including bryophytes), observable to the naked eye and nearly always identifiable when observed.
MTR	Mean Trophic Rank. A numerical score assigned to a survey length based on its macrophyte presence and abundance characteristics.
Nitrate	Dissolved or soluble or non-particulate nitrate.
Non-QD	Non-qualifying discharge under the UWWTD, with a population equivalent of less than 10,000.

NRA	The National Rivers Authority. A predecessor to the Environment Agency.
pe	Population equivalent.
Phosphate	Dissolved or non-particulate phosphate, normally analysed as soluble reactive (SRP) or by the molybdenum-blue method.
Pool	Either a discrete area of slow flowing water, usually relatively deeper than surrounding water, or between faster flowing stretches, as in a sequence of riffle-pool-riffle. Pools are deep and often turbulent, and scoured during spate flows.
Primary survey	When a survey is repeated for quality assurance purposes, the initial survey is termed the 'primary survey' and the repeat survey the '*audit survey*'.
PSP	Potential source of pollution. A term describing potential, non-QD-derived sources of eutrophication in riverine habitats.
QD	Qualifying discharge (usually from a WWTW) under the UWWTD, with a population equivalent of greater than 10,000.
RHS	River Habitat Survey. A method for assessing the physical character and quality of river habitats and impacts upon them.
Riffle	Fast flowing, shallow water whose surface is distinctly disturbed. This does not include water whose surface is disturbed by macrophyte growth only.
Run	Fast or moderate flowing, often deeper water whose surface is rarely broken or disturbed except for occasional swirls and eddies.
SA(E)	Sensitive Area (Eutrophic). An area of water which is considered to be eutrophic or which in the near future may become eutrophic if protective action is not taken, and recognised as such by designation under the Urban Waste Water Treatment Directive.
SCV	Species Cover Value. A value assigned to a species according to the percentage of the survey area it covers.
Site	This is the broad location where the survey is to take place, eg *x*km downstream of a waste water treatment works.
Slack	Deep, slow flowing water, uniform in character.
SNH	Scottish Natural Heritage.

SNIFFER	Scottish and Northern Ireland Forum for Environmental Research.
STR	Species Trophic Rank. A value assigned to a species on a scale of 1 to 10, designed to reflect the tolerance of that species to eutrophication. Low scores indicate tolerance or cosmopolitan distribution (ie no preference). High scores indicate preference for less enriched conditions or intolerance of eutrophic conditions.
Survey	The collection of data at one site according to the prescribed methodology.
Survey length	This is the sample area — the actual river *channel area* surveyed, between two fixed points on the bank. The survey length is 100m long for standard MTR surveys.
Survey season	The MTR survey season is mid-June to mid-September inclusive.
TDI	The Trophic Diatom Index. A method for assessing the trophic status of rivers using benthic diatoms.
u/s	Upstream.
UWWTD	The European Community Urban Waste Water Treatment Directive (UWWTD, 91/271/EEC).
WWTW	Waste water treatment works.

EXECUTIVE SUMMARY

1 The principal purpose of this manual is to provide comprehensive procedural guidance on how to carry out Mean Trophic Rank (MTR) macrophyte surveys to assess the trophic status of rivers, and on the use of the method for the designation of sensitive areas (eutrophic) (SA(E)) under the requirements of the EC Urban Waste Water Treatment Directive (UWWTD).

2 The guidance is a practical output from R&D project E1-i694 'Assessment of the Trophic Status of Rivers Using Macrophytes'. The project assessed the MTR for the purposes required of it under the UWWTD, made recommendations for improvements in the system and compared the MTR with other methods for the biological assessment of trophic status in rivers.

3 The manual describes what the MTR system is, for what purposes it can be used and how to use it. It gives guidance on where and when to undertake MTR surveys, how to carry out the macrophyte survey in the field, how use the information gained to calculate an MTR, how to interpret results for the purposes of the UWWTD and how to maximise that the quality of the information gathered. Uses of the method for purposes other than the requirements of the UWWTD are also considered.

4 The procedures described are intended as the standard method for undertaking MTR surveys, and as the standard macrophyte survey method to be used by the Environment Agency for the purposes of the UWWTD. The methodology is applicable throughout the UK and so the manual will be of use not only to Environment Agency staff but also to regulatory agencies in Scotland and Northern Ireland, statutory and non-statutory conservation bodies, and others interested in the trophic status of rivers.

KEY WORDS

Macrophyte survey, Urban Waste Water Treatment Directive, UWWTD, Sensitive Areas, phosphorus, nutrient, eutrophication, monitoring.

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1 FOREWORD

1.1 About this manual

1.1.1 Purpose of the manual

The principal purpose of this manual is to provide procedural guidance on how to carry out Mean Trophic Rank (MTR) macrophyte surveys to assess the trophic status of rivers, and on the use of the method for the designation of Sensitive Areas (Eutrophic) (SA(E)) under the requirements of the EC Urban Waste Water Treatment Directive (UWWTD, 91/271/EEC).

The manual describes what the MTR system is, for what purposes it can be used and how to use it. It gives guidance on where and when to undertake MTR surveys, how to carry out the macrophyte survey in the field, how to use the information gained to calculate an MTR, how to interpret results for the purposes of the UWWTD and how to maximise the quality of the information gathered. Uses of the method for purposes other than the requirements of the UWWTD are also considered. The manual provides a standard methodology and hence allows data to be collected in the same manner by all surveyors, eliminating differing interpretations of the method.

The method described is based on the survey methodology produced by the National Rivers Authority (NRA 1994a). It incorporates subsequent developments in the survey methodology and calculation of Mean Trophic Rank values (Holmes 1995, 1996), and takes account of recommendations made at a national R&D workshop to discuss methods used to assess trophic status (Newman et al 1997a, b – also in Dawson et al 1999a). Furthermore, it is based on a comprehensive evaluation of the MTR which used a dataset of more than 5000 surveys (Dawson et al 1999b). It is thus based on considerable experience and represents the best current practice.

1.1.2 Statement of use

The procedures described are intended as the standard method for undertaking MTR surveys, and as the standard macrophyte survey method to be used by the Environment Agency for the purposes of the UWWTD. The guidelines provided should be followed in all MTR surveys, to ensure that the data produced are of acceptable quality and are comparable on a national basis.

The methodology is applicable throughout the UK. This manual is therefore of use not only to Environment Agency staff but also to regulatory agencies in Scotland and Northern Ireland, statutory and non-statutory conservation bodies, and others interested in the trophic status of rivers.

The protocol and guidance given in this document supersede and replace those previously published in relation to macrophyte surveys for UWWTD monitoring purposes and to the MTR system (NRA 1994a; Holmes 1995, 1996; Newman & Dawson 1996; Environment Agency 1996a).

1.1.3 Format of the manual

A tabulated summary of the MTR method is provided below to give a broad overview of the methodology (1.2). This is then followed in Chapters 2–8 by detailed guidance on all the sections listed in the summary. The guidance is organised so that it progresses from general introductory information on the MTR system and its uses, to detailed survey procedures, interpretation of the results and quality assurance. Quality assurance measures which are integral to the survey method itself are shown in shaded boxes throughout. Key words are underlined in the tabulated summary and listed in an index at the back of the manual, to assist cross-referencing.

The manual should be read in full to gain a comprehensive understanding of the method and its application. Surveyors should familiarise themselves with the definitions given in the glossary, particularly the terms 'site' (the broad location of the survey), 'survey length' (the sample area) and 'survey' (the collection of data at one site according to the prescribed methodology).

1.1.4 Other outputs from this project

This is one of four outputs from the Agency's national R&D Project E1-i694 *Assessment of the trophic status of rivers using macrophytes*. The other three outputs are:

- R&D Technical Summary ES35 — *Assessment of the trophic status of rivers using macrophytes: evaluation of the Mean Trophic Rank.* This summarises the project findings.
- R&D Technical Report E39 — *Assessment of the trophic status of rivers using macrophytes: evaluation of the Mean Trophic Rank* (Dawson et al 1999b). This presents the main research findings and will be of interest to those involved with the development, management or implementation of biological methods to assess trophic status.
- R&D Project Record E1/i694/01 — *Assessment of the trophic status of rivers using macrophytes: supporting documentation for the evaluation of the Mean Trophic Rank* (Dawson et al 1999a). This presents supporting information and is intended for use by those involved with future development of the MTR and related methodologies.

1.2 Summary of the method

A summary of the MTR method is given below (cf DoE Standing Committee of Analysts 1987). Key words are underlined and are included in the index at the back of this manual.

WHAT IS MTR?	
1. Purpose	Assessment of trophic status and eutrophication impact.
2. Biota sampled	Macrophytes (plants identifiable with the naked eye).
3. Watercourses sampled	Rivers and streams. The method is not suitable for standing waters, canals (unless water flow is constant in one direction) or tidal rivers.
4. Underlying principles	Within the aquatic macrophyte flora there is a spectrum of tolerances to nutrient enrichment which can be expressed by assigning scores to species on a scale of 1–10: the higher the score (the Species Trophic Rank or STR), the lower the tolerance to nutrient enrichment. The response of the macrophyte community to nutrient status can be expressed by integrating the scores of the species present as a mean value, weighted according to the relative percentage cover of the individual species. The resulting value (the Mean Trophic Rank or MTR) increases with decreasing eutrophy.
5. Basis of operation	The macrophyte flora and physical character of defined lengths (100m) of watercourse are surveyed using a standard checklist. The presence, absence and % area covered by each macrophyte are recorded and used to calculate the MTR score. Physical parameters are recorded to aid interpretation.
FOR WHAT PURPOSES CAN THE MTR SYSTEM BE USED?	
6. Uses	The method can be used to give a qualitative assessment of whether a site is impacted by eutrophication and (for physically similar sites) downstream changes in trophic status. The method should not be used to compare the trophic status of physically dissimilar sites, nor should it be used to make comparisons between the trophic status of different rivers unless the rivers are the same type.
7. Applications	The principal application for which the method has been developed and tested is to assist in the designation of identified reaches as 'Sensitive Areas (Eutrophic)' under the EC Urban Waste Water Treatment Directive. The method should be equally applicable to the assessment of other point-sources of nutrients, but is not yet proven for other applications.
SURVEY PLANNING	
8. Alternative methods	A Diatom Quality Index (DQI) survey should be undertaken at the same time as the MTR survey if possible.
9. Sampling strategy	The location of survey sites varies according to the purpose of the survey. Less impacted 'control' sites may help determine eutrophication impact.
10. Logistics of sampling	A minimum of one survey per year for three years is recommended, each being undertaken at the same time within the survey season (mid-June to mid-September) and after several days of low or low–normal flow. Operator safety, shade, river flow and water clarity need to be considered when selecting a survey length. *continued....*

10. ....*continued*	Survey equipment includes sampling aids, camera and protective clothing/equipment. Surveyors should be familiar with the provisions of the Wildlife and Countryside Act and should follow appropriate health and safety guidance. Surveys can be undertaken by one operator, although multiple-staffing is recommended: surveyors should allow one person-day per survey although this may vary considerably.
11. Ancillary data collection	Background information on site geomorphology, pollution incidents and river management can be useful when planning and interpreting surveys.
HOW TO CARRY OUT AN MTR SURVEY	
12. Pre-survey preparation	An equipment checklist is provided. Surveyors should be familiar with the necessary health and safety guidance.
13. Field survey	The stretch to be surveyed (the survey length, 100m) is selected or located and if suitable for survey it is measured out and marked. Standard field sheets are used to record site and survey details. The macrophyte flora and physical character of the survey length are then surveyed by wading, boat, or walking along the bank. Sampling aids are used where necessary. All macrophytes present are recorded, together with the estimated percentage cover of each taxon (recorded as abundance classes: the species cover value or SCV) and the estimated percentage cover of overall macrophyte growth. Representative samples are taken for laboratory analysis if identification is uncertain. Physical parameters of the survey length are estimated, a sketch map drawn and a photograph taken.
13. Laboratory analysis	Samples taken on the field survey are identified shortly afterwards and representative specimens retained in a 'herbarium' for future reference.
DATA ANALYSIS AND INTERPRETATION OF RESULTS	
14. Data analysis	Survey data are in the form of qualitative (presence/absence) and semi-quantitative (estimates of % cover) records of macrophytes and physical characteristics. $MTR = (\sum CVS/\sum SCV) \times 10$, where $CVS = SCV \times STR$. MTR scores lie in the range 10–100.
15. Interpretation of results	Results are interpreted using standard 'decision trees' and general guidance on MTR scores found in a range of different rivers. Results are expressed qualitatively in terms of nine standard descriptors relating to the eutrophication status of the site and downstream impact.
QUALITY ASSURANCE	
16. Error and variability	Variability between surveyors in data recorded in the field can be reduced by correct application of the method and adoption of quality assurance. The impact of natural background variation in MTR within the survey season and between physically dissimilar sites, can be reduced by careful timing of surveys and selection of survey lengths. Three measures of confidence are assigned relating to the survey, the comparability of sites and the MTR score.
17. Quality assurance procedures	Quality assurance comprises measures integral to the survey method itself (eg on-site checks and multiple-staffing), training requirements and audit surveys. Two alternative audit protocols are provided.

2 INTRODUCTION TO MTR

This chapter describes the purpose of the MTR methodology, the biota used, the watercourses for which the method is suitable, the principles on which the method is based and a summary of how it operates. It then provides guidance on the applications for which the method can be used.

2.1 What is MTR?

2.1.1 Purpose

The MTR system is a biological method to assess the trophic status of rivers in the UK and the impact of eutrophication.

The definition of eutrophication according to the UWWTD (91/271/EEC, Article 2(11)) is:
"Enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned."

The definition of eutrophication adopted by the Agency in its proposed Eutrophication Strategy (Environment Agency 1998a) is:
"The enrichment of waters by inorganic plant nutrients, which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants affecting the quality of the water and disturbing the balance of organisms within it. Such changes may be undesirable and interfere with water uses."

2.1.2 Biota sampled

The MTR system is based on the presence and abundance of species of aquatic macrophyte. A macrophyte is defined as 'any plant observable with the naked eye and nearly always identifiable when observed' (Holmes & Whitton 1977). This definition includes all higher aquatic plants, vascular cryptograms and bryophytes, together with groups of algae which can be seen to be composed predominantly of a single species.

Macrophytes were selected for this method for several reasons.

- Species composition can change with increased nutrient concentration (2.1.4) and so can be used as a water quality monitoring tool to determine and monitor areas affected by nutrient enrichment.
- These changes in the macrophyte community can be highly visible and may be deemed 'undesirable' in terms of the definitions of eutrophication cited above (2.1.1). For example, they may result in the loss of conservation and amenity value, in addition to problems for abstraction licence holders and other water users (NRA 1994a).
- The macrophyte species recorded for these surveys are large and readily identifiable with the naked eye. There are relatively few species in a particular river area (approximately 20), so it is normally possible to identify all to species level when the necessary seasonal attributes are present.

- The rooted nature of many species means that absence of species is significant and this, as well as the presence of a species, can be used in the interpretation of survey data.

2.1.3 Watercourses sampled

The MTR methodology is designed for use in rivers and streams. The method is not suitable for assessing standing (lentic) waters, canals (unless the water flow is constant in one direction) or rivers with a tidal influence.

2.1.4 Underlying principles

The Mean Trophic Rank methodology uses a simple scoring system to derive a single index describing the trophic status of a site. The system works by allocating a Species Trophic Rank (STR) score to 128 aquatic plant species (Appendix 5 – Table A1). The scores range from 1 to 10. High scoring plants are associated with water bodies which are low in nutrients. Low scoring plants are either tolerant of eutrophication or are cosmopolitan in their requirements, ie have no preference. The response of the macrophyte community to nutrient status can be expressed by integrating the STRs of the species present at a site as a mean value, weighted according to the relative percentage cover of the individual species. The resulting value, the MTR, increases with decreasing eutrophy, with a theoretical maximum of 100 and a minimum of 10 (there is no score when scoring species are absent).

In undisturbed or un-degraded ecosystems, the plant community often contains many species, none of which tend to dominate to the detriment of any other, ie the system is in balance. Species with high STRs should be present and a theoretical maximum MTR score should be achieved based on the limits imposed by floristic diversity, flow regime (altitude), river size, catchment geology and water chemistry at a particular site. In degraded or disturbed ecosystems, the plant community may contain fewer species and one or two species with low STRs may be dominant. In these instances, a score somewhat less than the perfect score will be achieved. There is a scale of degradation and in between these two extremes lie the majority of riverine ecosystems in Britain.

The change from the perfect score can be used as a measurement of the impact or damage caused to the ecosystem by the disturbance. A predictive element to the MTR, allowing predictions of what MTR can be expected given a certain set of physical conditions (the 'perfect score'), is still only in the early stages of development. Never-the-less, the MTR system can be used to make an estimate of how degraded the ecosystem is from the expected norm (taking into account all other factors), and give an indication of the change in the macrophyte community from that norm using the guidance on the interpretation of MTR results given in this manual.

The development and testing of the MTR has focussed particularly on its use as a tool to assess eutrophication impact due to phosphate enrichment. Although eutrophication may arise from enrichment by compounds of either phosphorous and/or nitrogen, phosphorus is usually considered to be the element which limits aquatic plant growth in fresh waters because of its low availability in relation to plant requirements. Where it is limiting, an increase in the level of phosphate in the water should cause accelerated growth of those plants present or a change in the species composition of the plant community to reflect the change in phosphate concentration.

At very high concentrations of phosphate, the plant community is usually species poor because of the excessive growth of filamentous and unicellular algae and some high phosphate tolerant macrophytes. In these cases where the biological symptoms of nutrient enrichment are manifest, eutrophication as defined in the UWWTD and the Agency's proposed Eutrophication Strategy can be deemed to be taking place. In contrast, where the availability of a nutrient is sufficient so as not to limit plant growth, such as is usually considered to be the case for compounds of nitrogen, any increase in the concentration of that nutrient will not lead to changes in the plant community and thus eutrophication cannot be deemed to be taking place.

Evidence suggests that the MTR is particularly responsive to change in nutrient status at concentrations less than 1.0 mg l^{-1} P or 10 mg l^{-1} N, and even more so at less than 0.5 mg l^{-1} P or 5 mg l^{-1} N (Dawson et al 1999b). This implies that the MTR system may be most useful at detecting eutrophication impacts when the nutrient concentration upstream of (or prior to) the nutrient input, is less than 1.0 mg l^{-1} or 10 mg l^{-1} N, particularly when supported by other biological and/or chemical evidence. The level of eutrophication attributable to nitrate rather than phosphate at any one site cannot be established using MTR at this stage of method development. In many cases, however, the nitrate concentration is unlikely by itself to be limiting to plant growth, and phosphate is likely to be the limiting factor (Dawson et al 1999b).

2.1.5 Basis of operation

The method involves the survey of the macrophyte flora and physical character of defined lengths (100m) of watercourse using a standard checklist. The presence, absence and percentage area covered by each macrophyte are recorded and the data relating to scoring species (those assigned an STR) are then used to calculate the MTR score. Physical parameters are recorded to aid interpretation of results. Detailed procedural guidance is given in Chapters 3–8.

2.2 Uses of MTR

The MTR method can be used to give a qualitative assessment of whether a river site is impacted by eutrophication and (for physically similar sites) downstream changes in trophic status. It should not be used to compare the trophic status of physically dissimilar sites, nor should it be used to make comparisons between the trophic status of different rivers unless the rivers are the same type.

The principal application for which the method has been developed and tested is to assist in the designation of identified reaches as SA(E)s under the UWWTD (2.3). The methodology has been used extensively by the Environment Agency for this purpose.

The method should be equally applicable to the assessment of other point-sources of nutrients, but is not yet fully proven for other applications (2.4). Use of the system to date, however, is encouraging. For example, macrophyte surveys using MTR and the method of Haslam (DoE Standing Committee of Analysts 1987) have been used in Northern Ireland to indicate the location of eutrophication problems and to monitor trends in the trophic status of rivers (Oliver & Hale 1996). A combined approach using macrophyte, invertebrate and ecotoxicological work upstream and downstream of key discharges has been found to be useful, with the potential addition of the Trophic Diatom Index (TDI, 3.1.2). English Nature have used the MTR together with the Nature Conservancy Council macrophyte classification to examine the impact of discharges from small- and moderate-sized sewage works on small rivers (eg Southey 1995). Although there was no clear relationship between the two sets of results and percentage reductions in MTR score downstream of discharges were not great, possibly due to high phosphate-loading upstream, it is felt that the MTR shows much potential and that it is useful to use both systems when analysing changes of macrophyte floras over time.

2.3 Principal application: Urban Waste Water Treatment Directive

This is the principal application for which the Mean Trophic Rank has been developed and tested. The survey methodology and calculation of MTR are described in detail in Chapters 3–5 of this procedural manual and guidance given in Chapter 6 on interpretation of results. Before commencing surveys, Environment Agency staff should also refer to current internal guidance on information gathering for future reviews of SA(E)s for the rationale behind UWWTD monitoring (Environment Agency 1998b: supersedes NRA 1994b).

In brief, the MTR is used to provide evidence of eutrophication impact on riverine macrophyte communities, in order to support designation of identified reaches as SA(E)s under the Directive and to provide evidence of the specific impact of 'qualifying' discharges on such reaches.

2.3.1 Designation of Sensitive Areas

Sensitive Areas (Eutrophic) (SA(E)s) are water bodies which are considered eutrophic, or which in the near future may become eutrophic if protective action is not taken. They are identified using the criteria listed in Annex II of the Directive, with the definition of eutrophication as given in Article 2(11) (see 2.1.1 above). The size of discharges and type of receiving water are taken into account. Once SA(E)s are designated, discharge requirements can be set for 'qualifying discharges' (QDs) in terms of nutrient levels or a percentage reduction in nutrients. 'Qualifying discharges' are those with a loading of greater than 10,000 population equivalent (pe): they may discharge either directly into the SA(E), or indirectly into the relevant upstream catchment areas of SA(E)s, contributing to the pollution/eutrophication of these areas. However, no action needs to be taken (ie consents do not need to be determined) if it can be demonstrated that nutrient-removal will have no significant effect upon the level of eutrophication. In the case of most freshwaters, nutrient removal would usually be of phosphorus, the principal limiting nutrient in freshwaters.

A Government consultative paper was published in March 1992 (DoE et al 1992), proposing criteria for identifying SA(E)s and subsequent procedures. This guidance was finalised in March 1993, in Annex B of the paper published on the methodology for identifying SA(E)s (DoE et al 1993). Under this methodology, waters are only identified if affected by QDs. For rivers, the upstream limit of a SA(E) is either a QD or the point at which the symptoms of eutrophication become manifest. The downstream limit is where the effects are reduced to 'typical'. For riverine environments, the criteria relate to orthophosphate, chlorophyll *a*, algal biomass, water retention time, dissolved oxygen, fauna (fish/invertebrates), macroflora and microflora. The MTR provides information on the macroflora by providing an estimate of the degradation to aquatic macrophyte communities in these areas.

2.3.2 Assessment of eutrophication and the impact of qualifying discharges

The main pollutant causing eutrophication arising from QDs will usually be phosphorus. This phosphorus will usually be in the form of soluble reactive phosphate (SRP) and therefore be available immediately to submerged macrophytes downstream of the discharge. Given the relationship between MTR and phosphate concentration (Dawson et al 1999b), the MTR can be used to answer the two key questions required for evidence in support of SA(E) designation:

- is the river eutrophic, or shortly at risk of becoming eutrophic?
- what is the impact of the QD?

Guidance on sampling strategy and interpretation of MTR results to answer these questions is given in Sections 3.2.1 and 6.1. The latter includes flow-charts to enable decisions to be made in a consistent and structured manner. Results are expressed qualitatively in terms of two standard descriptors, one for trophic status and one for the downstream impacts of the QD.

2.3.3 Post phosphate-removal monitoring

It is anticipated that macrophyte communities previously affected by phosphate eutrophication will attain higher MTR scores after phosphate removal (phosphate-stripping) is installed at QDs. Although this response, or the speed at which it occurs, has yet to be demonstrated due to the early stage of method development, the MTR system should be used to monitor improvements in the macrophyte community after phosphate-removal has commenced. The information gained from this monitoring will not only provide direct operational information on the impact of the P-removal, but will also provide much needed information for the further refinement of the method. The latter includes information on the speed at which macrophyte communities respond to a reduction in P concentration; how recovery takes place (which species come back first); and the effect of P in sediments (how long it takes for phosphate-enriched sediments to cease to have an effect on the macrophyte community).

The success of biological methods at demonstrating an improvement in the trophic status of a system is dependent on the availability of a reliable and consistent historical data set. Lack of such a data set may limit the application of the methods to demonstrate an improvement in a historical context. For those SA(E)s designated under the 1997 review, however, post-phosphate-removal monitoring may be able to show measured improvements using data from the 1996 MTR surveys as the baseline for improvement.

In order to separate the effects of phosphate-removal from natural background variation in the MTR it may be necessary to carry out an examination of the time series of change to establish baseline variation in MTR scores. These data may be available by comparison with MTR scores from previous seasons, but care should be taken to ensure that all factors relating to the accuracy and comparability of MTR surveys prior to 1996 are satisfactory before undertaking such comparisons. If you are sure that any change in MTR score prior to phosphate-removal cannot be accounted for by changes in nutrient concentrations or other conditions then this variability can be used as a measure of natural background variation. It is anticipated that any changes due to phosphate-reductions will be superimposed on this natural change.

2.4 Other applications

2.4.1 Non-qualifying point-source discharges

In many river systems in the UK, a significant proportion of the phosphate-loading comes from WWTWs of less than 10,000 pe although surface water run-off and storm sewer overflow may also be significant sources of phosphorus in urban areas. These discharges do not qualify under the UWWTD for statutory improvement works to remove P from the effluent discharge. This means that eutrophication can be primarily caused by phosphate-loading from sources other than QDs and hence outside the legislative framework of the UWWTD. It also means that rivers are frequently degraded upstream of the QD, making the demonstration of an impact of a QD difficult to achieve in absolute terms. The MTR can be used to identify non-QDs which are having a significant impact on the macrophyte community in order to target these for future nutrient control measures where possible. Sampling protocol and interpretation of results is as for assessment of QDs (3.2.1 and 6.2.1).

2.4.2 Non-point source discharges

The phosphate-loading of many agricultural catchments may arise mainly from non-point sources, such as soil run-off and diluted slurry effluent. The use of the MTR is these circumstances is largely untried, but provisional guidance on sampling strategy and interpretation of result is given in 3.2.2 and 6.2.2. The information gained from such studies will help determine if the MTR system is capable of detecting the effects of non-point source discharges.

2.4.3 Catchment studies

Studies of the MTR over a whole catchment or sub-catchment may be considered for three purposes.

To improve the interpretation of MTR values, by placing them in a catchment context

The main inherent limitation of the MTR is that it is influenced to some extent by factors other than nutrient levels; in particular, by the substrate, underlying geology of the river and to some extent the flow regime. This means that to interpret the MTR in terms of trophic status it is necessary to compare results with values expected in a relatively un-impacted reach of a similar type. Such reaches, or at least similar reaches with less nutrient enrichment, may be found elsewhere in the catchment being surveyed.

A second limitation relates to the sensitivity of the MTR in detecting the impact of individual nutrient sources. In a complex environment, the impact of a nutrient discharge may not be manifest by the MTR for some distance downstream due to impact by other polluting factor(s) in the same discharge or by another discharge close by. In either case, interpretation of MTR results may be improved if the sampling programme includes surveys at regular intervals down the catchment to assess the varying influences on the macrophyte community (3.2.3).

To undertake a 'eutrophication audit' of an individual catchment to determine where nutrient control measures would be targeted most effectively

The MTR is recommended for this purpose provided its inherent limitations in terms of other influencing factors, as outlined above, are taken into account in the sampling regime and interpretation of data. Best practice will be to undertake surveys at intervals over the whole catchment (3.2.3). Reference should also be considered to the requirements of the Nitrates Directive (91/676/EEC).

To provide an overview of the trophic status of a catchment to compare with other catchments on an area, regional or national basis

The cross-comparison of actual MTR values between catchments is NOT recommended at the current time, except where catchments are of the same physical type. Even then, the validity of comparing MTR scores from similar sites in different river catchments has not yet been confirmed and so comparisons should be interpreted with caution.

Broad comparisons can be made between physically dissimilar catchments by interpreting the results on a site-by-site basis, taking into account all the potential influencing factors and using very broad standard descriptors of trophic status. In addition, where demonstrable and significant downstream changes in MTR can be observed, catchments may be compared on the basis of the relative degree of downstream degradation as demonstrated by changes in the MTR. This may help to prioritise those catchments which would benefit most by nutrient control measures. Specific guidance is given in 3.2.3 and 6.2.3.

2.4.4 Eutrophication management strategies

The MTR can assist delivery of eutrophication management strategies (eg Environment Agency 1998a) and of catchment or river-basin management plans in two ways.

Assessment and prioritisation of problems

The MTR can make a valuable contribution to the assessment of the nature and extent of eutrophication problems, which can then be prioritised and managed via action plans. The efficiency of these plans will be enhanced if they are formulated and progressed under the umbrella of either catchment or wider environmental management plans such as the Agency's Local Environment Agency Plans (LEAPs).

Data from all MTR surveys, whatever the primary application, will be useful for this purpose, although to a greater or lesser degree depending on the sampling strategy (3.2.4). Guidance on the interpretation of data is as for catchment studies (6.2.3). Emphasis should be placed on the balance of information available, including evidence from MTR, diatom (3.1.2) and chemical monitoring.

Whereas LEAPs will require only local collation of MTR data to identify problems within the catchment, national collation of data is required for eutrophication management strategy purposes.

Compliance monitoring

The MTR may potentially be used to assess the efficacy of eutrophication control measures and hence monitor compliance with targets. The capacity of the macrophyte community to respond to nutrient reduction measures, however, is poorly understood (2.3.3). Until such time as this understanding is increased, best practice will be to continue MTR surveys after nutrient control measures are in place. Guidance on sampling strategy is given in 3.2.4. All such post-nutrient reduction survey data should be collated nationally to allow further method development.

2.4.5 Temporal changes in trophic status

The MTR methodology is recommended for use to monitor temporal change in trophic status at a site over a number of years. Temporal change may be either a deterioration due to a nutrient input or an improvement in response to nutrient control measures. Although this application is largely untried, due to insufficient data, it is assumed for the interim that the MTR will respond to temporal changes in nutrient status in a similar fashion to changes on a spatial scale. The timescale of response can only be established once sufficient adequate data are available.

The general principles of post phosphorus-removal monitoring, as outlined in 2.3.3, apply to applications beyond the UWWTD.

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3 SURVEY PLANNING

This chapter describes the steps which should be taken when planning MTR surveys and should be read before the surveys are undertaken. The first step is to check that the MTR method is appropriate for the use required (see 2.3 and 2.4). The next steps are to consider alternative methods, devise a suitable sampling strategy, plan the logistics of the surveys (when and where to survey and what resources are required) and collect ancillary data. These steps are described below.

3.1 Alternative methods to consider

When planning biological surveys to assess river trophic status, it is important to choose the most appropriate methodology. Method selection requires recognition of the various options available and an understanding of their comparative strengths and deficiencies under a range of circumstances. This section outlines the available options and lists criteria to consider when choosing which option(s) to adopt.

3.1.1 Options

There are two biological methods recommended for the assessment of the trophic status of rivers: the macrophyte-based Mean Trophic Rank and the diatom-based Diatom Quality Index (a transformation of the Trophic Diatom Index). An introduction to the MTR is given in Section 2.1 and an outline of the DQI/TDI is given below. Although experienced biologists may also glean information on trophic status from other riverine biota, for example the benthic macro-invertebrate community, there is no validated standard method to do this. Use of such information should thus be used with caution and only to support evidence gained from one or both of the recommended methods below.

3.1.2 Trophic Diatom Index (TDI) & Diatom Quality Index (DQI)

The Trophic Diatom Index (TDI) was developed by Kelly and Whitton (1995a & b) for the NRA as part of an investigation into the use of plants to monitor rivers and in response to the needs of the UWWTD. It was further refined by Kelly (1996a, b & c), following testing by practitioners in Agency regions.

The method is designed for monitoring the trophic status of rivers and streams, and uses benthic diatom communities rather than the macrophyte assemblages used in the MTR system. Diatoms are widely used for monitoring water quality on the continent (Whitton & Kelly 1995), for palaeoecological studies of lake acidification in the UK (Battarbee 1984) and, more recently, lake eutrophication. In one instance (Anderson & Rippey 1994), a change from eutrophic to mesotrophic conditions following diversion of a nutrient input from a lake in N. Ireland was observed in a single season. As diatoms derive their nutrients directly from the water column and have generation times measured in days rather than months or years, it was thought that these might constitute a reliable tool for assessment of eutrophication in rivers.

Comprehensive procedural guidance on the TDI methodology is given in the TDI User's Manual (Kelly 1996b). Briefly, the method involves the collection of benthic diatom films from natural or artificial substrates within a 10m reach of river. Sampling of natural substrates is quick and easy, although sampling of artificial substrates requires two visits to a site. Permanent slides of the material collected are prepared and analysed in the laboratory. Taxa present on the slide are identified and the relative proportion of each taxon estimated. These data are then used to calculate an index showing the degree of eutrophication (the 'trophic diatom index' or TDI) and a second value indicating the contribution of organic pollution at a site. When used together, these enable nutrient-rich waters to be separated from those which are organically polluted. Organic pollution is frequently associated with high nutrients, but these nutrients are not necessarily the only factor determining success of a txaon in organically polluted water (Kelly et al 1996).

The index is based on 86 taxa and is derived from the weighted average equation of Zelinka and Marvan (1961), using taxon sensitivity to nutrient status, indicator value (spread around the mean) and abundance. Taxon sensitivity values assigned to individual taxa range from 1 (favoured by very low nutrient conecntrations) to 5 (favoured by very high concentrations of nutrients). TDI values can range from 0 (indicating very low low nutrient concentrations) to 100 (indicating very high nutrient concentrations). To facilitate comparisons with MTR assessment, the scale of the TDI is inverted so that low scores correspond to high nutrients and high scores to low nutrients (Kelly 1996b). Rather than run the risk of confusion by having two quite different versions of the TDI working in opposite directions, the 'new' diatom index (ie 100 - TDI) is referred to as the 'Diatom Quality Index' or DQI.

For the purposes of assessing trophic status, the applications of the MTR described in 2.3 and 2.4 apply equally to TDI/DQI. Macrophyte surveys have been traditionally used for conservation assessments of rivers, while diatoms have been linked with water quality assessments: both can now be used for trophic status assessment. Further information on the applications of the TDI/DQI is available in Kelly (1996a & b).

3.1.3 Criteria for deciding which method to use - MTR or DQI/TDI?

Given the two recommended methods for biological assessment of the trophic status of rivers, the next step is to consider their comparative merits and decide; (a) whether either method is suitable, (b) if so, which is the most appropriate or (c) whether both methods are required. Factors influencing this decision may include: the specific purpose and objectives of the survey; the survey/site conditions; the resources; and/or, expertise available.

It is recommended that for comparison with MTR results, diatom data is presented as the DQI rather than the TDI. This allows maximum compatibility between the data presented and thus assists communication of results to non-biologists.

Wherever possible when assessing the trophic status of rivers, **both** the MTR and DQI should be used. This includes monitoring both for UWWTD purposes and for other applications, guidance for which is given in Section 2.3 and 2.4. The two methods complement each other and produce results which are broadly in agreement in terms of relative values. Where results differ, this can often be related to poor site/sampling conditions affecting one of the indices (Dawson et al 1999b), although in some situations it may reflect a real difference in the response of the diatom and macrophyte communities to the prevailing trophic conditions, such as a difference in the time taken to respond to nutrient reduction measures (Box 1). The use of both methods has the advantage that a broader spectrum of the flora can be examined for the impact of nutrient inputs in sensitive areas, allowing judgements to be made on more comprehensive environmental information. However, the information gained from either method should not be used in isolation and should be put into context in the light of all information gathered at a site. It is likely that chemical data and physical habitat description will add valuable information to assist interpretation. The points listed in Box 1 should also be borne in mind.

Box 1 Factors to consider when deciding whether to use MTR or DQI/TDI

1. **River type**
MTR may be more applicable to slow-flowing lowland silty rivers than the DQI because of lack of suitable substrates for diatom growth. Use of artificial substrates extends the range of situations where DQI is applicable, although suitable positions to leave the artificial substrates are still required (Kelly 1996b). Water depth may limit the use of both methods.

2. **Shade**
Both macrophyte and diatom communities, and particularly their biomass, may be influenced by shading, such as that caused by bankside trees, suspended sediments or surface floating vegetation.

3. **Flow**
Neither method should be used after spates. For both methods, careful consideration should be given before undertaking surveys in circumstances where the flow from a point-discharge maintains river flows greater than would be expected (Boxes 2 & 3).

4. **Organic pollution**
If the effect of organic pollution is suspected then it is strongly recommended that the DQI method be used (in addition to the MTR, if appropriate), as this has a component to establish the extent of pollution integral within the method. If it is not possible to use the DQI method but an MTR macrophyte survey can be used, it may be necessary to do an invertebrate survey in conjunction with the MTR to establish the extent of pollution. The most comprehensive assessment could be provided if all three methods can be used: diatom, macrophyte and invertebrate. It should be noted that the effects of organic pollution on the MTR are unquantified at this time and information from invertebrate surveys carried out at the same time will be useful for refining the MTR method in future. Gross indications of organic pollution, such as the presence of sewage fungus, should be noted when using any of these methods.

5. **River management**
Macrophyte communities may be affected by weed cutting and other associated maintenance activities.

6. **Navigation**
The impact of navigation on the applicability of survey methods is varied. MTR surveys rely on clear water, but watercourses with boat traffic tend to more turbid than un-navigable reaches. Water clarity does not affect the DQI (TDI) to such an extent but makes finding suitable substrates difficult (Kelly 1996c).

7. **Nuisance value**
In some circumstances both diatoms and/or macrophytes can cause a nuisance with respect to intended water use. Diatom scums are particularly prevalent in spring and excessive growth of macrophytic algae late in summer may require management to eliminate the nuisance. In circumstances where there is a recognised nuisance from either diatom and/or macrophyte growths, it may be prudent to ensure that the assessment method(s) chosen includes the 'nuisance' element of the biota (ie DQI and/or MTR respectively).

continued.....

Box 1 Factors to consider when deciding whether to use MTR or DQI/TDI

.....continued

8. **Disturbance**
   Neither method should be carried out if conditions at the survey length are not typical of the survey site (see Box 2).

9. **Season**
   MTR surveys are restricted to the period between mid-June and mid-September (3.3.1). The DQI method is applicable throughout the year, access permitting, although it is recommended that studies are performed between spring and autumn (Kelly 1996b). For comparison purposes it will be necessary to carry out DQI surveys at roughly the same time of year as MTR surveys.

10. **Recovery period**
    When nutrient control measures such as P-stripping are put in place and an assessment of the subsequent recovery of the biota is required, the relative performance of the MTR and DQI in detecting improvements in trophic status over time must be considered. The speed of response of diatom and macrophyte communities to improvements in trophic status caused by P-stripping, however, is largely unknown at the present time and more data are required. It is likely that diatom communities will respond faster as they are entirely dependant on water column nutrients for growth. The influence of sediment nutrient characteristics on macrophyte recolonisation are as yet unknown*. The best practice would be to undertake both methods at sites where nutrient removal is in place, or is likely to be introduced.

11. **Harmonisation with other surveys**
    The DQI is easier and quicker to carry out in the field and, as a result of sample preservation, allows a greater degree of flexibility in the organisation of survey programmes than does the MTR. It may thus be more easily added onto an existing sampling programme, especially invertebrate surveys as the survey area used is comparable. MTR surveys may, however, be more valuable for comparison with historic data sets of the same site where only macrophyte data are available. MTR surveys are also more appropriate if wishing to harmonise with surveys for classification of river types for conservation purposes.

12. **Resources**
    The method used will be dependent on the expertise and equipment available and the cost of the survey. More time is spent in the field for MTR, but less in the laboratory.

* This is the subject of an ongoing Environment Agency funded PhD project.

3.2 Sampling strategy

3.2.1 Assessing the impact of point-sources of nutrients

The general sampling strategy for assessing all point-sources of nutrients, whether UWWTD qualifying discharges or not, is very similar to other biological assessment methods. An MTR survey should be undertaken from a site upstream of the discharge and compared with an MTR survey downstream of the discharge. More than one survey downstream will be required to assess the geographical extent of any impact. More than one survey upstream of the discharge, or in other physically-similar parts of the catchment, may be required to help determine whether the MTR is suppressed by factors other than nutrient enrichment. In cases where it is suspected that the downstream change in MTR is being influenced by factors other than trophic status (by increased turbidity, for example), there is justification for using information from other biological assessment methods, such as the DQI and the River Invertebrate Prediction and Classification System (RIVPACS), to give a more refined picture of the impact of the discharge.

3.2.2 Non-point source discharges

It may be difficult to pinpoint specific areas where degradation of the aquatic macrophyte community structure occurs unless a comprehensive study of the whole catchment is undertaken. However, surveys may be targeted around the areas where the potential for non-point source pollution is highest. Examples include: areas where the nature of the land use means that there is a high potential for sediment erosion; areas where the potential for farm effluents entering the river system is highest; and areas where run-off from hard surfaces in urban areas is occurring.

3.2.3 Catchment studies

To improve the interpretation of MTR values by placing them in a catchment context (2.4.3), surveys should be undertaken at regular intervals down the catchment to assess the varying influences on the macrophyte community.

To undertake a 'eutrophication audit' of an individual catchment, to determine where nutrient control measures would be targeted most effectively, surveys should be undertaken at intervals over the whole catchment. However, the inherent limitations of the method must be taken into account when selecting sites and interpreting data. Results must only be compared between physically similar sites (6.2.3).

To provide an overview of the trophic status of a catchment to compare with other catchments on an area, regional or national basis, the survey strategy is as outlined in the paragraph above. However, the limitations on comparison between catchments (2.4.3 and 6.2.3) must be taken into account when planning the surveys and interpreting results.

3.2.4 Eutrophication management strategies

To assess and prioritise problems on a large (eg national) scale, surveys of whole catchments or sub-catchments will be of most use. More restrictive surveys targeted at specific discharges (eg for UWWTD purposes or assessment of non-qualifying discharges) may provide a 'coarse' focus for initial prioritisation of areas worthy of more attention, but should then be followed up by more intensive surveys on a whole catchment or sub-catchment basis before recommendations are made regarding nutrient reduction measures. However, the limitations on comparison between catchments (2.4.3 and 6.2.3) must be taken into account when planning the surveys and interpreting results.

To monitor compliance with water quality targets after installation of nutrient reduction measures, MTR sites up- and downstream of the discharges in question should continue to be monitored after the nutrient reduction measures are in place. Control sites further upstream and perhaps also on physically similar rivers, should also be monitored to establish the baseline variation. Any changes due to the nutrient reduction measures will be superimposed on this natural variation.

3.3 Logistics of sampling

3.3.1 Timing of surveys

Macrophyte surveys should be carried out between mid-June and mid-September (the 'survey season') after several days of low flow or low–normal flow as opposed to high flow/spate. Although some macrophytes are visible outside this survey season, others are not and hence the MTR score will not be an accurate representation of the trophic status because of the missing species. Even within the survey season, differences in the growth patterns of individual species may result in changes in their relative abundance during the season, with consequent variation in the MTR score. To minimise such within-season differences in MTR score, surveys should be undertaken in close succession when comparing different sites on the same river within the same year, and at the same time of the survey season each year when comparing the same site in different years.

Rivers should not be surveyed at times of high flow as access is dangerous and turbid conditions mean complete and/or accurate data are unlikely to be obtained. Once spate water levels have dropped to, and remained at, more normal flow levels for several days, surveys can be resumed but the survey results may be affected and this will need to be taken into account when interpreting the data. The timing of the spate flow will determine which macrophyte species are able to grow back to their original abundance levels and which will be under represented for the remainder of the season.

Where surveys being compared cannot be undertaken at the same time of the survey season, caution should be applied when comparing results and allowance made for natural within-season variation. Macrophyte species have different seasonal growth patterns, some species exhibiting accelerated growth rates early in the season and others not attaining maximum size until late summer. This can result in changes in the MTR and the overall percentage cover from early to late summer.

3.3.2 Number of surveys per year

To assess a site for trophic status, it is recommended that a minimum of one survey per year for three years should be undertaken, with the surveys being carried out at the same time of the season each year.

A useful way to organise a survey programme to ensure that surveys are undertaken at the same time of the season each year, is to survey sites in the same order each year.

If a second survey is undertaken at a site within the same year, then there should be a minimum of seven weeks between surveys and allowance for within-season differences in growth must be made when interpreting results. It is recommended that such surveys are undertaken only for calibration purposes, to provide an indication of the within-season variation and to help when placing overall results into a wider context.

Although a minimum of three once-a-year surveys is recommended, to enable any inter-year variation to be taken into account, assessments of trophic status using MTR may be undertaken on the basis of a single survey in a single year. This may be particularly appropriate for catchment studies, where the aim is to gain an overview of the trophic status of a catchment in order to identify those areas which would most benefit from further investigation and/or eutrophication control measures.

The above guidance is consistent with that previously issued by the NRA and the Agency for UWWTD macrophyte surveying (NRA 1994b, Environment Agency 1998b). The NRA/Agency guidance is to carry out 4 surveys over three years (eg 1994, 1995 and 1996 for the 1997 review), with each site surveyed twice in one of the years, once in the earlier part of the season and again in the latter part, to obtain a better idea of seasonal growth.

The number of surveys per year is also subject to the following quality assurance recommendation (see also 7.2.2). Each year, each surveyor must either undertake a set minimum of MTR or other macrophyte surveys (the suggested minimum is five surveys per year), or attend a training course at which MTR surveys are undertaken. At the beginning of the survey season, surveyors who did not achieve the minimum requirement of [five] surveys in the previous year should not undertake further surveys until they have received MTR training.
(Note that this is referring to the number of individual surveys not the number of pairs/sets of surveys up- and downstream QDs. Refer to the glossary for definition of survey.)

3.3.3 Site and survey length selection

The **site** is the broad location where the survey is to take place, eg *x*km downstream of a waste water treatment works.

The **survey length** is the sample area — the actual area of river channel surveyed, between two fixed points on the bank. The survey length is 100m long for standard MTR surveys (with an option to survey a 500m length in addition: see Box 4).

Factors which need to be considered when selecting a survey site/length and assessing its suitability are listed in Box 2.

A map of the location of the site and survey length should be retained on file so that the survey length can be accurately located on return or audit visits. This map may be the sketch map completed on a survey (see 4.6.9) and/or a more general map (eg showing details of access, parking and other features outside the scope of the 100m sketch map).

On the first survey at a site, the reason(s) for the selection of the survey length location should be noted in the 'Comments' section of the field sheet and a record of these comments retained on file.

3.3.4 Conditions under which surveys should not be undertaken

Surveys should not be undertaken when survey conditions are atypical for the site or prevent an adequate survey, or when the suitability of the site has otherwise been compromised. Some examples of unsuitable survey conditions are listed in Box 3.

Box 2 Factors to consider when selecting MTR sites and survey lengths

1. **Operator health and safety**
   Follow health and safety guidelines in selecting the location of survey lengths.
2. **General physical character**
   The survey lengths chosen should be typical of the river, within the other constraints listed. If local knowledge is not available look further upstream and downstream of the proposed survey length to determine this.
3. **Water clarity**
   Try to avoid locating survey lengths where the visibility of the river bed is significantly impaired either because the water is deep or turbid. If the survey length is usually turbid or too deep to see the bottom of the channel then a 'best attempt' at surveying for macrophytes can be made (see guidance on sampling aids, 4.5.3).
4. **Shade**
   Although the degree of shade does not appear to influence the performance of the MTR at assessing trophic status (Dawson et al 1999b), it is advisable to avoid heavily shaded areas when selecting survey lengths.
5. **Water flow and velocity**
   Survey lengths should not be situated where water flows and/or current velocity compromise operator safety (refer to health and safety guidelines). Careful consideration should be given before undertaking surveys in circumstances where the flow from a point-discharge maintains river flows greater than would be expected, ie significantly more flow downstream of the discharge than upstream. In this situation, the physical conditions may affect the MTR score more than water chemistry.
6. **River management**
   Weed cutting and other associated maintenance activities including dredging will often have a major effect on the cover and biomass of plant communities. Over time, this may alter and maintain the dominance of different plant species from those naturally present. The frequency and timing of river maintenance should be considered when selecting sites and survey lengths, and the effects of the maintenance taken into account when interpreting results.
7. **Artificial structures**
   Survey lengths are often located in the vicinity of bridges for ease of access. It is preferable, however, if the length selected is situated so that it does not include structures such as bridges, gauging/syphon weirs, locks and concrete-lined channels within the survey length itself as these may affect the substrate type, marginal area type and flow pattern. Local trampling effects may also occur near such structures so an atypical vegetation pattern may be observed. Any structure is potentially dangerous to the surveyor(s). Where structures cause change in the flow regime of the river the survey length should be situated at a location most typical of the rest of the river.
8. **Location of the survey length in relation to a discharge being assessed**
   Where an assessment is being made of the impact of individual point discharges into a river (eg UWWTD surveys, non-qualifying discharges), site selection is also based upon a need to determine the effect, if any, of discharges and to avoid as far as possible other factors which influence macrophyte communities.

continued....

Box 2 Factors to consider when selecting MTR sites and survey lengths

8. *Location in relation to a discharge (....continued)*

   Standard 100m survey lengths should be as close to the discharge point which is being investigated as possible, within the constraints of the other factors listed. They should not be more than 500m from the discharge unless other over-riding factors determine otherwise, such as an additional effluent, storm overflow or tributary. The priority is to find 100m stretches with comparable physical characteristics upstream and downstream of the discharge. If sites of comparable physical character are not present within 500m of the discharge point but are present within 1000m, these should be chosen in preference to contrasting sites closer together. Sites so far apart should not be selected if there are other inflows. It is important that this modification from the norm is clearly documented. See also Box 5 on exceptions to surveying the full channel width.

   The first survey length downstream of the discharge should be far enough away from the discharge to avoid very localised effects of the effluent. It may be advisable to survey more than one length downstream of a discharge, to ensure that any impact is detected.

   Take into account the position of any stormwater/emergency overflows, and position the survey length accordingly.

9. **Comparability with other sites**

   The MTR is influenced not only by trophic status but also to some extent by the physical character of the survey length. Therefore, if a series of sites are to be surveyed along a river in order to assess downstream changes in trophic status, the sites to be compared should be as physically similar as possible. Assessment of site comparability is based upon degree of shading, substrate type, channel width, water depth, water velocity, water clarity and bed stability. If in doubt, use the suffix of confidence described in 4.6.12 as a guide as to whether survey lengths chosen are comparable, noting that if the suffix is likely to be 'c' then this survey length is not suitable for survey and a new more comparable survey length should be found if possible. When surveying new sites, time is saved by looking for similar suitable survey areas before commencing any surveying.

   If physically comparable sites are available, the downstream length in any consecutive pair of sites should be situated to reflect any observed change in vegetation. To assess if a noticeable downstream difference in the flora can be observed, the surveyor should walk along the bank or use a boat to carry out a fairly extensive assessment of at least 500m of river both upstream and downstream of the discharge. Note the position of any distinct observed change and describe briefly the difference in the downstream community as compared with the upstream macrophyte community.

   If an effect is noticed but there is no similar upstream survey length then the effect should be photographed and commented on. If no downstream effect is noticed, survey lengths typical of the river should be selected.

   When back channels and main navigation channels are present, survey lengths being compared should be positioned either all/both on a back channel or all/both on the main channel so the survey results are comparable.

Box 3 Conditions when surveys should not be undertaken	
1.	Do not carry out macrophyte surveys during steady/heavy rain and windy conditions as the disturbance of the water surface leads to reduced visibility and could affect operator safety.
2.	Surveys should not be undertaken after spates because of dangerous conditions for wading and the probable loss of plant material and disturbance of habitat caused by high flows. Do not underestimate the potentially serious effects of flooding, as even minor flooding will cause temporary changes in the relative composition of species at a site. It is very important to either avoid surveying after flooding or at least to reflect the flooding in the suffix of confidence for the survey. It is always best to survey after a period of low flow as the water is usually clear and macrophytes are easily visible.
3.	Where surveys are undertaken over a number of consecutive years, to gain an overall picture of the 'typical' trophic status over the period, periods of unusual flow should be avoided as they will not reflect the 'typical' situation.
4.	Try to avoid surveying navigated rivers at holiday periods or peak of summer as high boat activity leads to increased turbidity and a more dangerous situation for the surveyors.
5.	Do not survey macrophytes immediately after a weed-cutting operation or other management activity which may adversely affect the macrophyte community.
6.	Do not carry out a survey if conditions are atypical for the survey site. Atypical conditions may relate to large floating masses of filamentous algae, excessive turbidity, or recent weed-cutting/dredging. If floating masses of algae or high turbidity are normal for the site then consideration should be given to using an underwater camera during surveys (see 4.5.3).

3.3.5 Survey equipment

The following is a list of equipment required to carry out an MTR survey; it is reproduced as a checklist in Appendix 7.

- Safety equipment - refer to safety manuals and advice available from your manager or safety advisor
- Maps - Ordnance Survey 1:50 000
- Location and/or sketch map to enable accurate location of the survey length (if surveyed before)
- Standard record sheets + sketch map sheet (on waterproof paper if necessary)
- Summary of the MTR methodology and definitions reference sheets (optional) - Appendix 7
- Substrate reference and % cover reference sheets (optional)
- Pencil and pen

- Clipboard with waterproof shield/cover or a large clear plastic bag (to protect record sheet and make writing possible in damp conditions)
- Grapnel with depth markings on the rope
- Bank stick with depth markings
- Plastic bags, labels and tubes for small specimens
- Tape measure or measuring rope, stakes and mallet (to mark start and end of survey length)
- Identification and field guides (Appendix 3)
- Camera with a polarising lens and 200 ISO daylight film speed
- Hand lens (x10)
- Blackboard & chalk or wipe-clean board, non permanent pen and cloth (small, to include site details in the photographs)
- Underwater viewing aid (eg glass-bottom bucket or underwater TV camera, see Appendix 4 for details)
- Polarising sunglasses (optional)
- Optical range finder (optional) - Appendix 4
- Boat and additional safety equipment as required
- Copies of previous survey sheet(s) for site(s) to be surveyed (optional).

3.3.6 Wildlife and Countryside Act 1981

Macrophytes are protected under the Wildlife and Countryside Act, 1981. Whole plants should never be uprooted, and portions of scarce macrophytes should only be removed when absolutely necessary (under no circumstances must those rare species listed in Schedule 8 of the Act have any parts whatsoever collected). A list of relevant 'rare' species is given in Appendix 1.

Material collected should be confined to the minimum required for identification. If a rare plant is found, make records of it by photography, noting any distinguishing features of the plant in the field.

3.3.7 Health and safety

Surveyors should refer to health and safety guidelines before undertaking MTR surveys. Please note that the surveys always involve working in water, could involve contact with polluted water, could be undertaken by a lone worker (although this is not recommended, see 3.3.8) and/or could involve use of a boat.

3.3.8 Staffing level

Where resources allow, surveys should be carried out by a team rather than a single surveyor. A minimum of double-staffing is to be encouraged as contributing towards good practice, for the following reasons:

- it reduces inter-surveyor variation and thus improves the quality of the survey data collected;
- it improves the efficiency of the survey.

One of the most significant causes of inter-surveyor variation, and thus of reduced quality of results, lies in the estimation of percentage cover. The accuracy and consistency of these rather subjective estimates may often be improved by achieving consensus from a 'group decision' rather than relying on a single surveyor. Such group-conferring may also help resolve difficulties of macrophyte identification and survey length relocation.

Efficiency may be improved by allowing different tasks to be shared simultaneously. When assessing and recording the presence and abundance of macrophytes within the survey length, there are a number of items of equipment the surveyor is required to carry, and a number of tasks the surveyor is required to achieve. The surveyor must use a clip-board, glass-bottomed bucket and plastic bags/vials for specimens, whilst retaining a free hand to record items on the clip-board and another free hand to collect specimens. This can make the survey difficult and time-consuming, and as a result may also impair the quality of the results obtained. When two surveyors are present, the equipment and tasks can be shared. Other tasks may also be shared simultaneously in this way: for example, the sketch map, the assessment of the physical characteristics of the site, taking a photograph and taking a diatom sample (when a DQI survey is undertaken in conjunction with the MTR).

Minimal extra time accrues from double-staffing compared to single-staffing. For sites which are double-staffed for safety reasons, it may not represent any additional resource investment.

In cases where surveys are undertaken by teams of two or more surveyors, one member of the team should be charged with overall responsibility for the survey. The initials of this 'principal surveyor' should always be listed first on the survey sheet, before those of the co-surveyor(s). The 'principal surveyor' should be fully trained in all aspects of the method. Co-surveyors should be similarly trained, but exceptions are allowed as outlined in 7.2.4. When undertaking the survey, surveyors in a team should confer regarding definition of the survey length, definition of the channel, identification of macrophytes, abundance categories and overall percentage cover, and reach a consensus 'group' decision. This minimises problems of relocating the survey length and provides an immediate 'spot-check' on identification and cover estimation. Differences between surveyors can be discussed, and resolved if possible, on the spot. The 'principal surveyor' has the final decision in case of dispute.

3.3.9 Time required to carry out a survey

Assuming a survey team of two operators, the total time spent per survey (including preparation, travel to site, field survey, laboratory analysis and data analysis) is likely to take one person-day, although this may vary considerably depending on travel distance, ease of access to the site, the nature of the macrophyte community, the weather and the experience of the surveyors.

3.4 Ancillary data collection

Background information is needed about the macrophyte survey sites. The geological information will only need to be researched once for each site. The pollution and channel management information will need to be researched for each survey of a particular site. Find out what the geological type and operational management plan is for the area to be surveyed, and the nature of any known pollution incidents, before planning macrophyte surveys.

3.4.1 Geological and geographical information

The background data that should be researched from maps is rock type, altitude and slope.

Underlying geology/rock type: the geology of a site may influence the macrophyte community both through lithology and baseflow.

Research the rock types in the areas proposed for survey, by referring to geological maps, so the geology of the area can be taken into account. If survey sites on a river are situated on the same drift and solid types, it is probable that neither the lithology nor the groundwater contribution to base flow, are causing any observed downstream change in vegetation. If the sites are on different geological types it may be that any observed change in vegetation pattern is related in some way to the geology of each site.

Record both drift and solid rock types. The cross-section given on the bottom of each map can be of use in deciding on the underlying solid rock type, if it is not labelled on the map.

Altitude: site altitudes should be taken from 1:50,000 maps. It is recommended that estimates be made to the nearest 5m.

Slope: A mean slope between the two contours either side of a site should be measured. The slope is expressed by the following equation:-

$$\text{Slope} = c / x \quad \text{m/km}$$

where c = the difference in altitude (m) between contours on either side of the site, and x = the distance (km) between the two contours as measured along the course of the river. Use a map wheel to obtain this value.

3.4.2 Management work

Operational management work such as dredging and weed cutting have obvious effects on the results of macrophyte surveys. Before planning macrophyte surveys it is useful to find out if any work is planned or has been completed since the last survey. Surveying a site after extensive weed cutting or dredging will reflect the damage done to the macrophyte community by the activity. The timing of weed cutting is also important as different species grow at different rates and reach maximum size at different times of the growing season. Thus a weed cut early in the season will have a different effect than a later one and change the macrophyte community pattern.

Note the timing of any management work undertaken before the survey on the standard sheet. In subsequent years note any management work which has been carried out since the last survey as well as any planned work.

Types of management work:

- Dredging
- Piling: reinforcement of river banks with (usually) metal sheets, driven into the bank by a pile-driver
- Other types of bank reinforcement
- Bridge repairs
- Weed cutting

Source of information: Catchment Engineers and Flood Defence Engineers of the relevant authority. Work is planned in advance but is weather dependant.

3.4.3 Pollution incidents

Determine if any pollution incidents have occurred which may have affected the macrophyte community at a site. Note any pollution incidents that may have effected the macrophyte community on the standard sheet. Give details of date and nature of pollution.

Sources of information: Water Quality staff of the relevant authority.

3.5 Limitations of the method

3.5.1 Uses and applications

The MTR score is influenced to some extent by the physical character of the river as well as the nutrient status. This means that the method cannot be used to make a quantitative assessment of the trophic status of an individual site — only a qualitative assessment — and should not be used to compare the trophic status of physically dissimilar sites. At the present stage of method development the MTR system can only show change in trophic status reliably over a relatively short physical distance, such as upstream and downstream of a discharge, without other complicating factors coming into play.

3.5.2 Operator health and safety

The method is limited to sites where operators can safely undertake a survey. For example, deep water, high current velocity and bed instability may render a site unsuitable for survey (refer to health and safety guidelines).

3.5.3 Site and survey conditions

The method is limited to sites and occasions where the conditions are suitable. Conditions which may reduce the efficiency and accuracy of the survey include:

- adverse weather conditions
- high flows, spates and flooding
- poor water clarity
- heavy shading
- presence of artificial structures
- river maintenance such as weed cutting or dredging
- navigation activity
- atypical conditions.

These factors should be considered when selecting site and survey lengths (Box 2).

3.5.4 Plant growth stages

Macrophyte survey methods can only be utilised during the summer months (mid-June to mid-September) due to the growth and dieback cycle of certain species (3.3.1). Differences in seasonal growth patterns between species may also result in variation in the MTR score within the survey season. Surveys undertaken at a site over a number of consecutive years can thus be compared with confidence only if taken at the same time of the survey season every year.

Surveyors should also be aware of natural fluctuations in the occurrence of certain species in rivers (eg *Ranunculus*). Care should be taken when interpreting absence of particular species that it is not a temporary absence. Detailed site knowledge and consultation with riparian owners may be necessary to determine this.

3.5.5 Difficulties resulting in surveyor error and/or inter-surveyor differences

The most common sources of surveyor error and variation between surveyors are: differences in estimates of macrophyte cover; mis-identification of macrophytes; missing species that are present only in isolated small patches; differences in judging whether specimens are 'in' and 'out' of the channel; and errors in accurately locating the survey length. All can be reduced by provision of adequate training, correct application of the method and adoption of quality assurance measures (see Chapter 7).

4 HOW TO CARRY OUT AN MTR SURVEY

This chapter describes the survey methodology, starting with an overview (4.1), then progressing to detailed procedural guidance on preparation (4.2), the field survey itself (4.3–4.6) and laboratory analysis (4.7). The method is summarised in Figure 3 in the form of a flow chart and in Appendix 7 as a checklist, either of which can be used as a field 'prompt sheet'.

4.1 Overview of the methodology

The macrophyte survey method chosen is based on the 'Blue Book' Method B (DoE Standing Committee of Analysts 1987). It can be summarised as follows.

1. A standard length of watercourse (100m) is selected or located and assessed to confirm its suitability for survey. If suitable it is measured out and the ends marked (the 'survey length'). Standard field sheets are used to record site and survey details.
2. The macrophyte flora and physical character of the survey length are then surveyed by wading, boat, or walking along the bank. Sampling aids are used where necessary.
3. All macrophytes present are recorded, together with the estimated percentage cover of each taxon (recorded as abundance classes: the Species Cover Value or SCV) and the estimated percentage cover of overall macrophyte growth. Representative samples are taken for laboratory analysis if identification is uncertain.
4. The physical character of the survey length is recorded by estimating physical parameters, drawing a sketch map and taking a photograph.

4.2 Preparation and pre-survey checks

Before going out on survey, surveyors should ensure that they have all the equipment they need, that they know the precise location of the survey lengths to be surveyed and that they are familiar with the necessary health and safety guidance. An equipment checklist is provided (Appendix 7).

Upon arrival at the survey site, the surveyor should confirm that the site and/or survey conditions are suitable for an MTR survey (see Boxes 2 and 3). Think again if:

- the suffixes of confidence for the survey and comparability are C and/or III
- there has been a recent temporal perturbation (eg spate or weed-cutting)
- flows are high and/or the water is turbid
- there is heavy/steady rain and/or windy conditions
- an alternative method is more appropriate.

4.3 Site and survey details

The appropriate site details such as name, river, date, time and surveyor's initials are recorded on the standard survey record sheet (see Appendix 5). In cases where surveys are undertaken by teams of two or more surveyors, one member of the team should be charged with overall responsibility for the survey. The initials of this 'principal surveyor' should always be listed first on the survey sheet, before those of the co-surveyor(s), to help the auditing process (see 7.3.6).

4.4 Marking the survey length

4.4.1 Length of river to be surveyed

For all applications, the standard survey length should be 100m, with macrophyte abundance recorded on the 9-point abundance scale C (see 4.5.5 for abundance scales). One exception is allowed for wide and deep rivers (Box 4). Where extra information would assist in the interpretation of data, the surveyor also has the option to undertake a 500m survey (Box 4).

When surveying a survey length for the first time, measure the actual length accurately using a tape measure. Mark each end of the survey length with a short stake or ranging pole which is clearly visible from the river channel.

If suitable details for relocation are included on the sketch map for subsequent surveys of the same length at the same site, then the length may be measured out using the system of pacing described below in conjunction with the sketch map, instead of using a tape measure. As an alternative to pacing, a 10m rope can be used, but this requires at least two people on site to make it an efficient method. If in any doubt, use a tape measure on each visit.

Regularly check on the number of paces needed to measure out the required survey length. This will vary for each surveyor and should be calculated before the beginning of field work. Mark out on the ground a 10m length and count the number of paces it takes to complete this distance. Repeat the exercise until confident that only a small variation occurs. Multiply up the figure obtained to determine the required number of paces for each survey length. If the error in pacing out the survey length is more than ± 10% then the actual length should be measured with a tape measure. This also applies where irregular pacing is anticipated due to obstructions or where pacing could only be undertaken in the channel.

4.4.2 Width of channel to be surveyed

The survey method covers those 'river' macrophytes contained within the 'channel area'. Records of 'bank' species are not made unless the survey is also for conservation purposes. Non-native and 'weed' species (Appendix 2) should be recorded.

Channel area definition:

All macrophytes seen submerged or partly submerged in the river, at low flow levels, within the survey length. These are considered to be 'river' plants. At the sides of the river all macrophytes attached or rooted on parts of the substrata which are likely to be submerged for more than 85% of the year are included.

Bank area definition:

The 'bank' is defined as that part of the side of the river (or islands) which is submerged for more than 50% but less than 85% of the time.

As it is best to survey macrophytes when the river has been at low flow for several days, the definition of channel area is fairly easy to interpret in a consistent manner. Obviously some degree of judgement and common sense is required to decide whether a macrophyte species is in the channel. Macrophytes overhanging the channel but not rooted in the defined channel area should not be counted. In general, records will be for those macrophytes which occur in the region of the river which is rarely uncovered, and those shallow sections which have an upper limit that may be exposed for a maximum of 50 days in any one year.

'Bank' macrophytes are those plants that occur above the limit of the river plants, and are thus out of the water for more than 50 days in any one year, yet will be submerged or partly so, during average flow periods.

4.4.3 Location of the survey length

If having completed a survey the results appear to have been affected by the physical constraints of the survey-length location, then consideration should be given to moving the location of the survey length within the guidance given in Box 2.

Quality assurance

If using the pacing system, each surveyor charged with determining the upstream and downstream limits of the survey length must check, at the beginning of each survey day, the number of their paces required to measure out the survey length. Do this for 10m as suggested above.

The survey length should agree with the relocation features marked on the sketch map.

Decisions regarding channel definition — which specimens are 'in' and which 'out' of the channel — are a common cause for inter-surveyor differences. Application of strict discipline is thus required: always check whether the roots of an overhanging specimen are in the channel or not, and do not be tempted to record specimens which are not rooted in the channel just because they 'score'. If a species is only recorded from the waterline, mark this on the field sheet (this will help clarify disputes between primary surveyor and auditor).

Box 4 Non-standard survey lengths

1. **Exceptions to the standard 100m survey length**

   If it is absolutely impossible, in a large river, to find two 100m sites of comparable character within close proximity of a discharge being assessed then choose 50m reaches of similar character, provided that the river is at least 10m wide (so that the survey area will be >500m^2).

2. **Optional surveying of 500m survey lengths, in addition to the 100m length**

   Where extra information would assist in the interpretation of data, the surveyor has the option to undertake a 500m survey in addition to the standard 100m length survey. The 500m (which must include the original 100m survey length) is surveyed in its entirety as a separate survey, using a 5-point scale for recording macrophyte abundance rather than the 9-point scale used for 100m surveys (see 4.5.5 for abundance scales). It is not possible to convert the data collected from the initial 100m to the 5-point scale and combine this with data collected for an additional 400m. The MTR is not affected by the use of the 5-point scale in place of the 9-point scale but more information and more resolution of abundance changes can be gained by using the 9-point scale.

   The additional 400m can be placed at either end of the initial 100m or split either side of it according to site circumstances to give a continuous 500m survey length. Gaps between the survey lengths are not allowed.

   The aim of carrying out the 500m survey is to obtain a fuller species list in order to verify the interpretation of trophic status from the 100m survey. In many cases the 500m survey will act as a 'quality check' on the location of the 100m survey length. In such cases, a 'working' MTR may be calculated from the 500m survey data, but this must only be used to compare with other 500m 'working' MTRs (eg upstream-downstream pairs) and to verify that the interpretation of trophic status from the 100m survey(s) is correct. In most cases, the MTR calculated from a 500m survey will not be significantly different from that derived from a 100m survey. As a precautionary measure, however, 'working' MTRs from 500m surveys **SHOULD NOT BE USED** for reporting purposes.

   If a 500m survey is carried out, this does not need to be re-surveyed every year but may be repeated every 5 years for comparative purposes **IF** great changes in the 100m survey data occur.

Box 5 Exceptions to surveying the full channel width

In all cases every reasonable attempt must be made to survey the full survey-length. There are a few exceptional cases where it is acceptable to modify the approach.

1. **Wide and deep rivers**

   In some very wide and deep rivers it may be impractical to carry out a survey of the full channel width on all surveying occasions. In such rivers, where the central channel may be devoid of vegetation or cannot be accurately recorded due to depth/turbidity even using an underwater camera, a 5m wide (minimum) strip down one side of the channel (ideally with little tree shading) can be surveyed. Where the impact of a discharge is being assessed, the downstream survey length must always be on the side into which the effluent discharges. In watercourses where an effluent tracks along one bank only for at least 500m downstream it may not be suitable to carry out a full width survey on all occasions either and, therefore, a 5m (minimum) strip can be surveyed. In such circumstances the whole river width must be surveyed initially so that results from the whole channel can be compared with the selected $500m^2$.

2. **Mature islands**

   Where the impact of a discharge is being assessed and a mature island is located within the survey length, only the side on which the discharge enters should be surveyed.

3. **'Black holes'**

   No gaps/'black holes' must be left in a survey length except under the following circumstances. If the majority (>80%) of a site can be surveyed by wading but the remainder is deep or rapid and it is not practical to survey using a boat and camera/glass-bottomed-bucket then this may have to be left as a 'black hole'. This must be clearly mapped and discounted in all future surveys. The 'black hole' should be totally excluded from the survey: it should not be included in estimations of plant cover or physical attributes (except for width).

4.5 Carrying out the macrophyte survey

Assess the presence and abundance (in terms of percentage cover) of macrophytes within the survey length and record this information using the standard field sheet (Appendix 5). In terms of survey technique, the majority of survey sites can be divided into two basic types: those that are wadeable and those requiring a boat to allow access to all areas of the site.

4.5.1 Survey technique: wadeable survey sites

At sites where it is assessed to be safe to do so, the full survey length and channel width is surveyed by wading. At the majority of sites a second operator will be required for safety reasons (but see 3.3.8).

Wading should be in an upstream direction so that any substrate disturbed does not obscure the visibility of the survey length both for ease of observation and safety reasons.

Where all but a small proportion (< 20%) of the survey length is accessible by wading it is acceptable to walk for a short distance along both banks observing the macrophytes and to investigate for submerged macrophytes using a grapnel.

The operator should wade in a zigzag manner across the channel, frequently investigating all habitat types present. The operator should cross the channel a minimum of 4 times in each 10m of the survey length as shown in Figure 1. Obviously this has to relate to visibility and is not prescriptive. For example, on wide but wadeable rivers with clear water it will not be necessary to cross the channel as frequently.

During wading, record the species present and think about the percentage of the survey areas covered by each species. Use sampling aids as appropriate (4.5.3). Include both MTR-scoring species and non-scoring species. Although only scoring species contribute to the MTR score, it is difficult to ignore non-scoring species and all species contribute to the overall percentage cover.

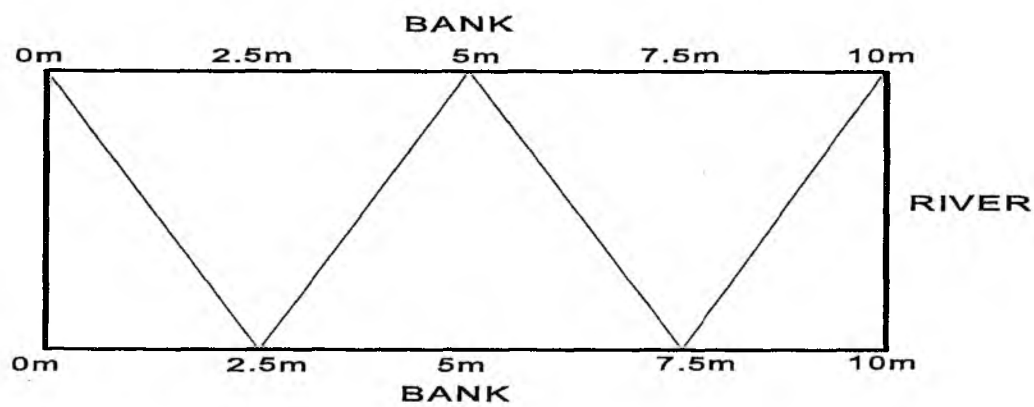


Figure 1 Diagrammatic representation of survey method

Take particular care to examine all small niches within the survey site to look for small (≤25cm^2) patches of species. Such patches are easy to miss but their non-recording can result not only in inter-surveyor differences but also an erroneous MTR.

Detached macrophyte material, except for actual floating macrophyte species such as *Lemna* sp and *Azolla*, should be disregarded. If a macrophyte is stranded above the water, eg in low flow conditions, then it should not be recorded on the standard checklist. A note of the species, should however, be made in the 'Comments' section along with observations of the amount stranded and any obvious reasons for stranding.

Where sites are being compared, as in UWWTD monitoring, specimens attached to artificial structures should only be recorded if a similar structure is present in both/all sites included in the comparison. A note should always be made of recorded specimens which were attached to artificial structures.

Once all macrophyte species in the survey length have been recorded wade/walk back along the survey length, specifically observing the amount of each species present and the overall percentage of the channel covered by macrophyte growth (4.5.5). On the standard field sheet (Appendix 5), enter the appropriate Species Cover Value (SCV, see 4.5.5) next to each macrophyte species and the estimate of the overall percentage cover of macrophytes.

4.5.2 Survey technique: non-wadeable survey sites

At sites where the channel is narrow (about 5m or less wide) but the water is too deep to wade, if the channel macrophytes can be clearly seen by walking along both banks and using a grapnel to retrieve macrophyte species for identification then this is sufficient. In narrow channels it may be impractical to use a boat.

At sites where the water depth is too great to wade and flow is slow, a small boat should be used. Safety guidelines should be followed.

The boat used should ideally be light and very stable for ease of transport and operator safety. Rowing or paddling is the most useful form of propulsion while surveying as this causes minimal damage to the macrophytes and allows greater manoeuvrability throughout the survey length.

Traverse the river in a zigzag manner inspecting all the habitat areas frequently. A minimum of 4 angled crosses of the channel in each 10m should be undertaken so that the maximum distance from the surveyor to the channel surveyed is 2.5m (Figure 1). On wide rivers it may not be necessary to cross the channel as frequently.

While traversing the channel, record the species present and think about the percentage of the survey area covered by each species. As for wadeable sites, include both MTR-scoring species and non-scoring species, take particular care to examine all small niches within the survey site to look for small (≤25cm^2) patches of species, but disregard detached material except for floating species. Record specimens attached to artificial structures only if a similar structure is present in other survey lengths with which the results will be compared and make a note of recorded specimens which were attached to artificial structures. Use sampling aids as appropriate (4.5.3).

After recording all macrophyte species present in the survey length, return along the length specifically observing the cover provided by each macrophyte species and considering the overall cover (4.5.5). On the standard sheet (Appendix 5), enter the appropriate Species Cover Value (SCV) next to each macrophyte species and the overall percentage cover estimate.

4.5.3 Sampling aids

It is important that the bed of channel is clearly visible, to enable accurate assessment of the species present and their abundance. In circumstances where the bed is not clearly visible due to deep or turbid water, or due to reflections from the water surface, observation of submerged species can be aided and errors reduced by the use of a glass-bottom bucket, an underwater TV camera and/or a grapnel (Appendix 4), as described below.

General guidance

For wadeable surveys, it is strongly recommended that a glass-bottom bucket is used to aid observation of macrophytes. A grapnel may be used to retrieve submerged macrophytes for identification from small areas of deep water, if necessary.

At deep-water sites where it is not possible to see the river bed unaided and for surveys by boat, an underwater TV camera or a glass-bottom bucket must be used to locate the position and assess the abundance of any macrophytes which cannot be seen from the surface. Use a grapnel to retrieve submerged macrophytes for identification. Binoculars can also be useful to scan the margins so that species present in small quantities, particularly if amongst a large stand of other macrophytes, will not be missed.

In deep and or turbid water the estimates of percentage cover for submerged species may have to be based entirely on observations from a underwater camera and/or glass-bottom bucket. Submerged species present in very small amounts may still be missed if the water is turbid.

If the underwater camera and/or glass-bottom bucket is used for a survey at a particular site, then it must also be used at any other site with which this is being compared.

Where visibility is severely impaired, use an alternative site or survey length if possible. Otherwise use the same surveyor for sites which are to be compared. If clarity is poor, direct comparisons of overall percentage cover and submerged species percentage cover should be treated with extreme caution if used at all.

Underwater TV camera

When using an underwater camera it is possible to see an area of approximately 1–2m wide with reasonable clarity in very turbid water. During the survey the camera should be used every few metres across the deep section of the river channel, as necessary. The boat must be rowed very slowly to ensure stability of the camera and accurate identification of submerged species. It is recommended that an estimate of the abundance of each species is made for each traverse of the river and the abundance estimates for that area combined to give a total estimate of percentage cover in the whole survey area.

The camera unit incorporates a light source which can help visibility in deep/turbid sites, but this should be used with care as it uses much more power so the battery time is greatly reduced. The clarity of the water will determine the number of times it is necessary to lower and rotate the camera lens so that 360 degrees can be observed. If necessary a small weight (see manufacturers guidelines) can be attached to the base of the camera to ensure greater stability and upright orientation. In silty/muddy sites avoid contact with the base of the river channel so no disturbance of the bed occurs leading to reduced visibility.

Grapnel

A grapnel may be used to retrieve submerged macrophytes for identification from areas of deep water. It is recommended, however, that the grapnel is NOT used to 'search' for macrophytes as a substitute for visual observation, due to the following problems:

- fine-leaved and deeply rooted macrophytes will not be found unless a direct hit is made, and therefore will either be missed entirely or under-represented;
- 'bushy' species such as *Elodea* will easily be collected by grapnel and their abundance may therefore be over-estimated.

Use of a grapnel alone will lead to high levels of inaccuracy in both the records of submerged species and the estimation of overall percentage cover.

Grapnel hauls should only be used when necessary, to retrieve macrophytes for identification or determine if macrophytes are present, as they can damage or uproot macrophytes. Particular care should be taken in an area with high conservation or aesthetic value.

4.5.4 Identification of macrophyte species

Identification should be to species level where possible. Take a field identification guide, which gives distinguishing features and shows which species are easily confused, into the field. Recent synonyms are listed in Appendix 5 (Table A1). It may also be useful to take into the field a copy of the survey sheets/results from the previous survey(s), as this may minimise gross identification errors and help ensure sparely-distributed plants are not overlooked. Previous results must be used with care, however, as the macrophyte community may have changed and/or the results may contain errors — they should only be used in a final check, and not as a first point of reference.

Certain species can only be identified when fruiting bodies or flowering parts are present; and even then only with difficulty. If identification to species cannot be achieved, for example due to absence of seasonal diagnostic features, and all other routes to identification fail (see below), then record only to the level to which you are confident (eg genus), even if this then renders the specimen 'non-scoring'.

Macrophyte species identified in the field should be checked for positive identification features. This takes an experienced surveyor very little time, ensures that rarer species are not overlooked and recorded as their more common counterparts, and reduces the likelihood of macrophyte species with superficially similar features being incorrectly identified.

Macrophyte species positively identified in the field should be recorded on the standard record sheet. When a species unfamiliar to a surveyor is found it should be identified in the field if possible but a representative sample should also be taken back to the laboratory for confirmation of the identification. A small, representative sample should be taken and placed in a plastic bag or tube without any additional water, together with a waterproof label. Normally a slip of waterproof paper or semi-opaque matt film, labelled in pencil is sufficient; alternatively pre-marked consecutively-numbered strips can be used with the number recorded on the MTR field form. When using plastic bags, blowing air into the bag before sealing it also helps to maintain the specimen in a healthy condition. On the label, record site, survey number, date, sampler's initials and unidentified specimen name, eg 'unident. 1'. On the standard record sheet, the unidentified species should be recorded in the 'other species' section, using the same name for the labelled sample so there can be no confusion on return to the laboratory. This is particularly important when more than one macrophyte from the same survey needs further investigation.

Particular care should be taken over the identification of *Ranunculus* species, as testing of the methodology has shown mis-identification of *Ranunculus* species to be a common cause of surveyor error, and thus of error in the MTR (Dawson et al 1999b). If in doubt, a representative sample should be taken back to the laboratory for confirmation of identification, or identification confirmed by an expert. Remember that if still in doubt, only record to the genus: '*Ranunculus* species indeterminate'. Where you are confident that two or even more species or apparently differing forms of *Ranunculus* are present, but you cannot be confident about the precise species, then it is allowable (or probably preferable) to record each species separately as '*Ranunculus* species indeterminate #1', '*Ranunculus* species indeterminate #2' etc, provided identification notes are made in the 'Comments' space and representative specimens are preserved in a herbarium for future identification/comparison.

Representative samples of algae and bryophytes should be taken to the laboratory for closer examination so that their that identification can be confirmed.

If the species identified is unfamiliar to all members of staff, is an unusual find for the river sampled or identification is not 100% positive, send the specimen to an expert for confirmation. If there is sufficient expertise in-house then an internal expert can be consulted. If such expertise is not available an external specialist must be contacted. BSBI county recorders are a useful source of local expertise. [Surveyors who have been on a training course run by Dr Nigel Holmes can currently send difficult specimens to him (Alconbury Environmental Consultants, The Almonds, 57 Ramsey Road, Warboys, Huntingdon, PE17 2RW) for verification, provided every effort has been made to identify the species beforehand.]

If possible, representative material of all species regularly encountered in surveys should be collected and maintained in a herbarium (see 4.7.2). This will make accurate identification of difficult material easier and will aid in the training of new staff.

Quality assurance

If possible, confer with survey colleagues to confirm identification. Preserve representative samples of 'difficult' specimens and place in a herbarium for future reference if necessary. Annotate the field sheet to indicate those taxa for which specimens have been placed in the herbarium.

4.5.5 Estimating macrophyte abundance

Macrophyte abundance is expressed in terms of the percentage of the survey length covered. This should be estimated by imagining a bird's eye view of the channel. For estimates of individual species, it is necessary to imagine the abundance cover of each, regardless of whether several species are intermingled or overlap.

Percentage cover estimation of filamentous algae can be particularly difficult. Determine whether the algae are forming a continuous or broken covering of the substrate.

For both overall percentage cover and individual species cover estimation it is useful to calculate what a one metre square patch of macrophyte represents for each survey length, eg 0.01%, 0.5% etc, before commencing surveying.

Overall percentage cover estimate

This is an estimate of the total percentage of the channel area covered by macrophytes, including both MTR-scoring and non-scoring species. Picture the survey area from above in two dimensions, ie length and breadth, and then use one of the methods in Box 6 to estimate the percentage cover.

Box 6 Methods of estimating overall percentage cover

Option 1

Imagine moving all the macrophytes to the one end of the survey length. The area covered will correspond to the overall percentage cover, for example in a 100m survey length an area of macrophytes completely covering a section which is 25m long × channel width will have 25% cover. If 500m was used then 25m × channel width would correspond to only 5% cover.

Option 2

If the majority of the vegetation is confined to strips along the margins of the river, the overall percentage cover may be estimated in the following manner:

marginal area covered, m^2 = length of marginal vegetation cover × width of marginal vegetation

total area covered, m^2 = marginal area + other areas

Total percentage cover = [(total area covered)/(total area of survey length)] × 100

Individual species percentage cover estimates

For all percentage cover estimates of scoring and non-scoring species, the whole survey area surveyed equals 100%, ie the individual species percentage cover estimates are a percentage of the whole survey area and **NOT** of the overall percentage cover estimated.

Estimate the percentage cover of each macrophyte species, then, depending on the percentage cover scale chosen, allocate each macrophyte a Species Cover Value. Use the C scale for surveys of 100m length and the A scale for surveys of 500m length.

The alternative Species Covers Value class scales are:-

Scale A (for 500m survey)		**Scale C** (for 100m survey length)	
A1	<0.1%	C1	<0.1%
A2	0.1–1%	C2	0.1–1%
A3	1–5%	C3	1–2.5%
		C4	2.5–5%
A4	5–10%	C5	5–10%
A5	>10%	C6	10–25%
		C7	25–50%
		C8	50–75%
		C9	>75%

In the rare event that a percentage cover is estimated as being precisely on the border between two categories and a judgement cannot be made than a value for the upper category should be recorded, thus for example if exactly 1% then C3 is recorded.

When all species have been allocated a Species Cover Value add up the percentages, in the field, to check that they correspond to the overall percentage cover estimated for that survey length (however, see Quality Assurance note).

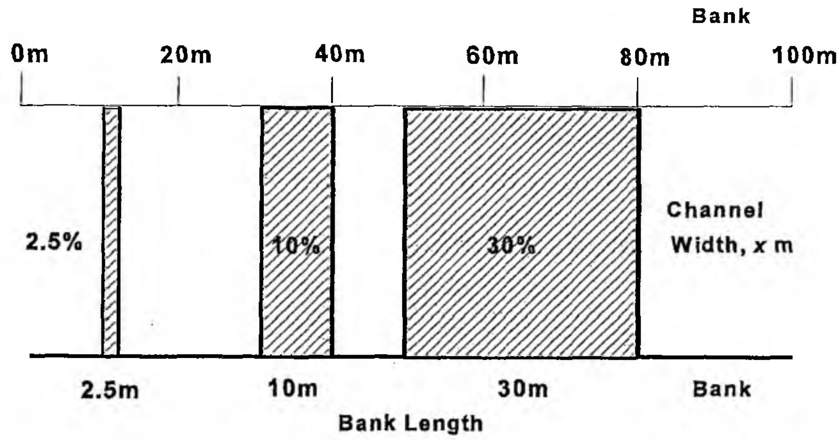
When assigning percentage cover to macrophyte species it is strongly recommended that a systematic approach is adopted to make the process easier and more accurate. Use one of the methods described in Boxes 7 and 8. As a double-check when estimating small areas of cover, it may be useful to work out beforehand the area of pieces of survey equipment, and use these for reference: for example, an A4 recording sheet (0.06 m^2) or the base of a glass-bottom bucket.

Survey areas choked with vegetation

At sites where macrophytes are very abundant the site may become choked with vegetation. For surveys at these sites it is difficult to estimate percentage cover for individual species. The birds-eye view method of recording cover should be taken. It may be necessary to use a grapnel and underwater TV camera/glass-bottom bucket to search for submerged species which may be surviving under other macrophytes. Record any species found from such searches and estimate their abundance based on observations using the underwater camera or glass-bottom bucket. Grapnel hauls should NOT be used as a means of estimating abundance (4.5.3).

Box 7 Estimating percentage cover of individual species: width method

1. Stand on one bank facing across the river channel to the opposite bank. Imagine a rectangle made between the banks and channel width, as illustrated below:



2. The whole survey length multiplied by the channel width equals 100%. Work out how long the bank length needs to be to illustrate an actual area of channel corresponding to a particular percentage cover. Visualise dividing up the bank length so that rectangles of area represent the range of percentage covers described by the SCV classes, and use this to allocate the appropriate SCV for each species.

3. Using Scale C for the survey length a macrophyte must cover the following bank length × channel width areas:

Scale point (SCV)	Percentage cover	Corresponding length on bank for 100m survey length	Corresponding length on bank for 500m survey length
C1	< 0.1	< 0.1	< 0.5
C2	0.1 - 1	0.1 - 1	0.5 - 5
C3	1 - 2.5	1 - 2.5	5 - 12.5
C4	2.5 - 5	2.5 - 5	12.5 - 25
C5	5 - 10	5 - 10	25 - 50
C6	10 - 25	10 - 25	50 - 125
C7	25 - 50	25 - 50	125 - 250
C8	50 - 75	50 - 75	250 - 375
C9	> 75	> 75	> 375

This method has the advantage that the lengths on the bank are constant for a particular survey length and cover scale used, regardless of channel width. The bank lengths MUST, however, be calculated for each combination of survey length and cover scale used. If the width varies considerable along the survey length, take this into account.

Example

For a 100m survey length using Scale C, a macrophyte covering an equivalent area of 6m × channel-width will be allocated an SCV of C5.

Box 8 Estimating percentage cover of individual species: square metre method

1. Estimate the approximate average width of the channel.
2. Calculate the equivalent square metre areas that need to be covered in order for a macrophyte to be awarded a particular SCV.

   For 100m surveys using Scale C, refer to Table A2 in Appendix 5, highlight the most appropriate width column and use this as a guide.
3. Estimate the number of square metres covered by each species within the survey length and allocate the appropriate SCV.

Example

For a 100m survey length, channel width 5m, using Scale C, a macrophyte must cover the following areas:

Scale point (SCV)	Percentage cover	Equivalent area (m^2)
C1	< 0.1	< 0.5
C2	0.1 - 1	0.5 - 5
C3	1 - 2.5	5 - 12.5
C4	2.5 - 5	12.5 - 25
C5	5 - 10	25 - 50
C6	10 - 25	50 - 125
C7	25 - 50	125 - 250
C8	50 - 75	250 - 375
C9	> 75	> 375

A macrophyte covering $6m^2$ would be recorded as C3.

NB These figures need to be recalculated for ANY DIFFERENCE in survey length, channel width or abundance scale.

Quality assurance

Check the overall percentage cover estimate by estimating the percentage of bare substrate and adding this to the overall percentage macrophyte cover: the total should be 100%.

Check the SCV estimates of individual species, by adding up the individual percentage cover estimates to make certain that they at least equal the overall percentage cover estimate. If they differ check the estimations to discover where the under- or over-estimation has occurred. This MUST only be done at the survey site: NEVER re-evaluate estimates after departing from a site.

NB It is possible for the sum of the individual percentages to be legitimately greater than the overall percentage cover where macrophytes overlie each other. Indeed, it is possible to have more than 100% cover of macrophytes in terms of SCVs, where the channel is choked with vegetation (see above). It is recommended that all taxa (scoring and non-scoring) are recorded and their cover assessed; this will allow an assessment of the total percentage cover of species, to compare with the overall percentage cover.

Difference in percentage cover values is the most common source of difference between primary and audit surveys of the same survey length. It is very important that training is given in the estimation of percentage cover values and that all surveyors are familiarised with the training on an annual basis. Do not guess the percentage cover: make reasoned estimates consistent with observation.

4.5.6 Biomass of macrophyte taxa

It is recommended that quantitative or semi-quantitative assessment of biomass is NOT included in routine (eg UWWTD) MTR monitoring. If a situation arises, however, whereby a particular species has the same Species Cover Value at two sites being compared, but its biomass is obviously greater at one because the depth of the stand is greater, then a comment should be made in the 'Comments' section and suitable photographs taken if possible.

4.5.7 Assigning a measure of confidence in the survey

Having completed the recording of macrophytes the surveyors should assess, on a scale of A to C, how accurately they feel the results reflect the prevailing situation at the site. This is an assessment of the typicality of the results given the constraints of water chemistry, weather, together with impacts such as the effects of weed cutting or site management. For example, the survey may have been hampered and perhaps rendered meaningless by:

- temporal perturbations such as recent river management (dredging, weed cutting, herbicide application, disturbance due to flood defence works such as bank reinforcements) or extreme flooding events, which may have influenced the macrophytes;

  and/or

- survey conditions which reduce the accuracy of the survey, eg poor survey conditions (turbidity, high discharge due to recent rain or very wet or windy conditions) or excessive blanketing algae or floating vegetation growth obscuring the view or smothering other vegetation.

Note that confidence in the results of a survey may be restricted by either one or both of the above factors.

Surveyors should score on a scale of A to C the degree to which the above may have distorted their findings:

- A - data not affected or any effect limited to less than 25% of the site
- B - the accuracy of records in 25–50% of the site influenced to a considerable degree
- C - the accuracy of records in >50% of the site influenced to a considerable degree

This should be recorded on the record sheet (see Appendix 5). The factors which potentially distorted the accuracy of the survey should be identified in the 'Comments' section.

The importance of objective interpretation cannot be over-emphasised here. Decisions are based on an individual's interpretation of what are typical conditions, to what extent those conditions have been deviated from and whether this has had an effect.

It is strongly recommended that surveys with a suffix of confidence of 'C' should not be used for interpretation of trophic status, ie *there is sufficient cause for concern that the MTR results do not represent the prevailing trophic status at the site.*

4.6 Assessing and recording physical variables

4.6.1 General method

After recording the macrophyte information re-traverse the survey length, observing and entering details of the physical variables on the form provided in Appendix 5. The grapnel, bank stick/ranging pole and/or underwater camera/glass-bottom bucket can be used to give an indication of the substrate type at sites where the channel bed cannot be directly observed. Mark the grapnel rope with 0.5m divisions and use it to determine the depth of the water, or use the bank stick/ranging pole. It should be obvious, from grapnel throws to retrieve macrophytes, if a change in depth has occurred within the channel.

The assessment of physical variables is NOT expected to be as precise as the macrophyte assessments, but merely an important element which should be used to help in:

i) assessment of how comparable sites are;

ii) providing information which in the future may help in more rigorously assessing the relationship between macrophytes and physical variables.

Orientation of the left and right banks is determined by the direction of flow. When facing downstream, the left bank is on your left hand side and the right bank on your right hand side.

In order to ensure that data are consistent, all variables should be recorded in a manner so that they relate to estimates in previous years. This may mean that the following categories/classes are recorded for some physical characteristics: 1 = <5%; 2 = 5–25%; 3 = >25% as well as actual percentages (actual percentages MUST be recorded). It is preferable to record percentages to the nearest integer value (ie no decimal places). If a particular feature is absent, then record this as 0% (category 0): do not leave data entry spaces/boxes un-filled.

Recording of features which are present in less than 0.5% of the survey area will not usually be required unless that particular habitat type contains the only occurrence of a scoring species. Such recording may also be required if TDI/DQI surveys are being carried out at the same site and the particular type of habitat is cobbles or boulders in amongst gravel or sand and that is the only suitable substrate for sampling diatoms. In either case, a note should be made under 'Comments' on the field sheet and care should be taken to mark the position of such small habitat patches on the accompanying sketch map.

Quality assurance

Check, before leaving the site, that all data entry spaces/boxes have been completed as required.

4.6.2 Width

The width is the channel width for which macrophyte species have been recorded, as defined in section 4.4.2, including any area of substratum above the actual water level that has been surveyed.

The first time a survey length is surveyed the width of the channel should be measured using a tape measure/rope with 0.5m divisions or an optical range finder (Appendix 4). If the width varies noticeably along the survey length then several width measurements should be made.

Record varying widths by entering the actual percentage in the appropriate boxes on the standard sheet. More than one category may be recorded. For repeat surveys it should be sufficient to estimate the width by one of the methods described below.

i) Use of a calibrated optical range-finder.

ii) If the survey length is easily/safely wadeable or a convenient bridge is present at a deep water survey length, pace out the width.

iii) If (i) or (ii) are not practical, determine channel width using the following method. Place a reference point on the ground, estimate by eye the distance across the channel then pace a greater distance than the estimate of channel width from the reference point along the riverbank. Turn and face the reference point, compare the distance to the reference point with the channel width and decrease the distance to the reference point until it matches the channel width.

Quality assurance

Optical range finders are designed to measure certain ranges so check that the one used is suitable for the width being estimated. Check the calibration regularly.

If the width estimates vary greatly from the original width measurements it is necessary to use a measuring device to check the data recorded for present and future surveys.

If a bridge is used to pace out channel width make sure that the channel under the bridge is the same width as the channel in the length surveyed.

Pace-to-metre ratios should be calculated as under section 4.4.1 and regularly checked. Ratios when wading in water should be calculated separately from ratios determined on the bank, but pacing in water should be avoided if at all possible. All ratios are person-specific (non-transferable!).

4.6.3 Depth

Record the depth by entering actual percentages in the appropriate boxes on the standard sheet (and categories if required for comparison with historical data). Measure the depth at various points along the survey length — the number and exact location of the measurement points should depend on the variability of depths encountered when surveying for macrophytes.

Measure the depth to the nearest centimetre by using a marked bank stick, ranging pole, metre rule or a grapnel with depth divisions marked on the rope. When recording depth, face the narrow edge of the measuring equipment into the current. In deeper water a grapnel rope with depth divisions at 0.1m intervals should be used to measure depth by lowering it vertically. When marking the grapnel rope the height of the grapnel must be included: for example, if the grapnel is 0.2m tall then the first mark on the grapnel rope should be 0.3m above that, representing a total depth of 0.5m.

> ***Quality assurance***
>
> Ensure that depth markings on bank stick, ranging pole, metre rule or grapnel rope are clear and accurate before commencing the survey day.

4.6.4 Substrata

Estimates should be based on a birds-eye view and should only include particles which are visible and the equivalent superficial layer under macrophytes. If shapes of underlying larger particles are distinct under a layer of fine particles such as silt or clay then the larger particles should be recorded. When the shapes of underlying particles are not distinct then the fine particles should be recorded. If the surveyor feels this is not sufficient then extra information can be recorded in the 'Comments' section.

The combination of substrata is recorded by placing the actual percentage cover in the appropriate box. As many substrata as are present should be recorded, although see 4.6.1 regarding features present at less than 1% cover. The percentage of each substrata category should be rounded to the nearest percentage point. No decimal points should be calculated. This ensures satisfactory consideration of experimental and observational error in recording. Percentage classes/categories may be recorded in addition to actual percentage values, if required for comparison with historical data.

The substrata classes are:

Bedrock	-	exposure of underlying rock not covered by alluvial deposits
Boulders/Cobbles	-	> 64mm (half-fist size or larger)
Pebbles/Gravel	-	> 2–64 mm (half fist to coffee granule size)
Sand	-	> 0.0625–2mm (smaller than coffee granules and unlike silt/clay, abrasive to the hands)
Silt/Clay	-	< 0.0625mm (have a soft texture)
Peat	-	dead vegetation undergoing bacterial decay in stagnant deoxygenated water – strictly pure peat, not fine peaty deposits over more substantial substrate.

The actual measurements given relate to the longest axis of each particle. Any rock with one or more sides greater than 256mm long is classed as a boulder.

The particle size categories follow an adapted Udden-Wentworth system. When irregular shaped particles are observed the longest axis length determines category assignment.

> ***Quality assurance***
>
> Take a copy of the reference sheet provided in Appendix 5 to each site.
>
> Check that the total of classes estimated is possible. Total up the substrata percentage cover which should equal 100%. Check that changes in substrate composition have not occurred due to management or flooding events.

4.6.5 Habitats

Allocate a percentage to the appropriate habitat types. Percentage categories may be recorded in addition if required for comparison with historical data. The habitat types are POOL, RUN, RIFFLE and SLACK, as defined below. Note that although these definitions are similar to those used for many other biological surveys, they are NOT the definitions used for the River Habitat Survey methodology (Environment Agency 1997).

Pool - Either a discrete area of slow flowing water, usually relatively deeper than surrounding water, or between faster flowing stretches, as in a sequence of riffle-pool- riffle. Pools are deep and often turbulent, and scoured during spate flows.

Riffle - Fast flowing, shallow water whose surface is distinctly disturbed. This does not include water whose surface is disturbed by macrophyte growth only.

Run - Fast or moderate flowing, often deeper water whose surface is rarely broken or disturbed except for occasional swirls and eddies.

Slack - Deep, slow flowing water, uniform in character.

> ***Quality assurance***
>
> Surveyors should regularly familiarise themselves with habitat variable definitions by consultation with other surveyors and by measurement of selected substrate types.

4.6.6 Shading

This is the percentage of the channel area affected by shading, NOT the percentage of the bank on which vegetation causing shade stands. The shading for each bank is recorded separately.

For the left bank, estimate the percentage of the whole channel area surveyed that is shaded by vegetation/structures from the left bank when the sun is directly overhead (ie at 12 noon). In a similar manner, estimate the percentage of the whole channel shaded from the right bank. If the total shading of the channel is needed then the two figures can be added together (theoretically this can be more than 100%). Refer to Figure 2.

When estimating the amount of shading, refer also the sketch map (4.6.9).

Three shade categories are defined: none, broken and dense.

None	-	no shading
Broken	-	some direct sunlight hits the water surface in the shade-affected area when the sun is directly overhead.
Dense	-	5% or less of the shade-affected area receives direct sunlight when the sun is directly overhead.

Record the actual percentage in the relevant shade box. Percentage categories may be recorded in addition if required for comparison with historical data.

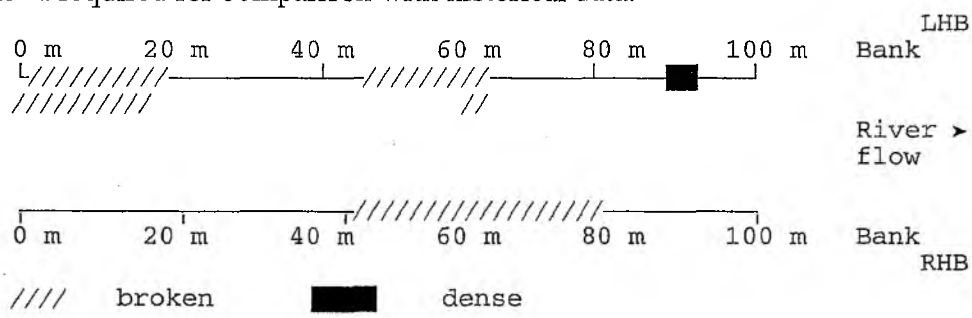


Figure 2 Illustration of shading

(Only shading affecting the channel is counted, therefore in Figure 2, where shading blocks cross the channel definition line they are counted as a half block)

The channel illustrated in Figure 2 would be recorded as:-

Shading	Left bank	None **91**	Broken **8**	Dense **1**
	Right bank	None **97**	Broken **3**	Dense **0**

Quality assurance

Carefully follow the method for estimating shade described and refer to the sketch map. If you are not sure about actual measurements, record the shading of the channel on the sketch map very carefully and on return to the office check with a colleague.

4.6.7 Water clarity

Record the actual percentage of the channel in each water clarity category. More than one category may be present as a survey length may be clear in the shallow margins and progress through cloudy to turbid as the water depth increases. Percentage categories may be recorded in addition, if required for comparison with historical data.

Clear	-	Channel substrate is clearly visible at all depths, as are macrophyte species.
Cloudy	-	Slightly discoloured with a moderate load of suspended solids and partially reduced light penetration. All clumps of macrophyte species can be located on the substrate of the river channel but the view of them is partially distorted. A small piece/single shoot of a macrophyte species may be missed.
Turbid	-	Strongly discoloured, carrying a heavy load of suspended solids and having greatly restricted light penetration. The channel bed is obscured and submerged macrophyte species are indistinguishable from substrate and water. This will lead to a reduction in accuracy and efficiency of the method.

Quality assurance

Consider the clarity throughout the length while surveying and assign percentages accordingly. It is likely that the same category will apply throughout a 100m survey length.

4.6.8 Bed stability

The following 4 classes are used to define bed stability:

Solid/firmly bedded	-	eg bedrock/compacted clay, increased flow has little effect
Stable	-	eg boulders/pebbles/gravel, unlikely to be significantly altered by increased flows
Unstable	-	eg gravel/sand/silt/mud, likely to be dislodged by increased flows
Soft/sinking	-	eg deep silt/mud, makes channel unwadeable, bank stick penetrates easily into substrate.

Record the actual percentage of the channel in each of the above bed stability categories. Percentage classes/categories may be recorded in addition, if required for comparison with historical data.

4.6.9 Sketch map

The purpose of the sketch map is to enable future relocation of the survey length and is not a record of individual surveys. It is not necessary to make detailed plans of each survey.

Fill in required details on standard sketch-map record sheet (Appendix 5), eg river name, site name, date etc.

Draw a sketch of the survey length, showing only in the broadest terms the general physical character of the site. This should include important vegetation stands and permanent reference features (such as a distance from a bridge or footpath sign) which would enable anyone else to find the survey length with great precision in the future. In addition, mark on any unusual features such as 'islands' of substrate supporting vegetation. In deep water, depth can be easily measured using a grapnel.

The distance markings on the standard sketch sheet do not indicate which direction the macrophyte survey should be undertaken. If starting at the upstream end of the survey length and moving in a downstream direction, the left side of the paper will correspond to the left bank and the direction of flow will be from the bottom to the top of the paper. If starting from the downstream end and moving in a upstream direction (this may be preferable for safety reasons - follow health and safety guidance), then turn the map upside down. It may be helpful to draw in 'landmark' features before starting the sketch map, or to mark on the bank the mid-point of the survey length, for reference.

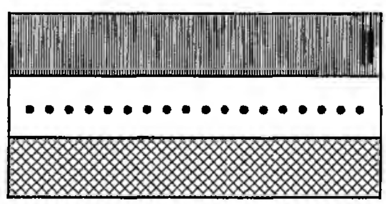
Main features to mark on sketch map:

Location of river and its pathway
NGR for the start and end of the survey length
Width of channel - the width included in the survey
Relocation features - for both ends of the survey length if possible
Shading position and type - broken or dense
Grid north (found from OS map)
Dominant macrophyte stands
Extent of riverbanks - riverbank (for the sketch map) is defined as the area before an adjacent land use starts
Adjacent land use - for example arable, pasture, factory, waste, set aside, houses/gardens
Depth of water - in m across the channel width

Broken shade should be indicated by:

Dense shade should be indicated by:

Macrophyte stands should be indicated by:



Label clearly.

Appendix 6 gives examples of sketch maps which are more than adequate.

Quality assurance

Pace out 10m lengths and check that the relevant features are marked on the sketch map in the correct location. Check that the orientation is correct.

It may be necessary to redraw the sketch map on return to the office to ensure labels etc are legible. Do not use personal shorthand in the final map as others will not be able to correctly translate this.

File all sketch maps with their corresponding field records. It is recommended that a short description of each survey length location is appended to a map (preferably 1:10 000) showing the location of the survey lengths. It is useful if this includes notes on access.

When using sketch maps to relocate survey lengths take photocopies into the field and leave the original in the file.

4.6.10 Photograph

A colour photograph should be taken of the survey length to visually record its general character and should include a feature (eg ranging pole) for scale. The use of a polarising filter to reduce surface reflection and a date facility on the camera are recommended.

Write the date and an identifying code or site name and river name on a small blackboard or wipe-clean board and place this, unobtrusively, in the photograph. Depending on the direction of the sun stand at one end of the survey length and take a photograph along the length of the river to gain a representative impression. Record the identifying code on the record sheet.

Additional photographs may also be taken to illustrate a change in vegetation between sites. When photographing channel vegetation, it is useful to include a reference object to indicate scale.

Quality assurance

Note any distinguishing features of the photograph (it is NOT sufficient to rely on these type of features alone - use the suggested labelling method). Label films and have each film developed as soon as it is finished. On return of developed film, refer to the relevant survey sheets and label each photograph with river, site name, date and surveyors' initials. Catalogue all photographs: file in groups under (for example) river name or catchment name, in an album or index type box file so they can be easily retrieved.

If using a box file, place each photograph in an envelope which has previously had the river and site name, date and surveyors' initial marked on it. Include the unique database site reference number on the envelope.

Make sure it is simple to cross reference with survey sheets and any computer based data.

4.6.11 Comments

In this section report any unusual features of the survey length, eg excessive growth of a particular macrophyte or a lack of macrophytes with no obvious cause. Record any problems encountered while surveying. Note distinguishing features of the survey length so that it can be relocated on subsequent occasions.

4.6.12 Assigning a measure of confidence in the comparability of survey lengths

When undertaking surveys to assess downstream changes in trophic status, it is necessary to assess how physically comparable are the sites being compared. Having undertaken both the sketch map and the physical inventory, identify on a scale of 1 to 3 how comparable the sites are and record this on the standard record sheet (Appendix 5). This assessment should be recorded at the time of survey or shortly afterwards.

The factors under consideration for comparison are Width, Depth, Substrata, Habitats, Shading, Water Clarity and Bed Stability.

- If 5 or more of these characteristics are similar for more than 75% of the site for each pair of survey lengths then assign category **I**.
- If 3 or 4 of these characteristics are similar for more than 75% of the site for each pair of survey lengths then assign category **II**.
- If 2 or less of these characteristics are similar for more than 75% of the site for each pair of survey lengths then assign category **III**.

It is strongly recommended that surveys with a suffix of confidence of III should not be used for interpretation of trophic status — *ie there is sufficient cause for concern that any differences in MTR between sites may be due to factors other than nutrient enrichment.*

4.7 Laboratory Analysis

4.7.1 Equipment

Binocular microscope, microscope slides
Hand lens × 10
White tray, forceps, dissecting needle
Identification keys
Plant press
Mounting paper and glue
Refrigerator

4.7.2 Reference collection (herbarium)

A reference collection of dried/pressed macrophyte specimens should be compiled and added to as new species are found in the area. Fruiting and flowering parts should be included. Verify identification of the fresh specimen with other experienced members of staff. Once pressed, label each specimen and list its key identification features. Do not include rare species in the collection but use photographs and annotated field drawings instead. The reference collection would be best kept in a cabinet with many shallow draws to avoid crushing of the dried specimens. As dried specimens are fairly brittle care should be taken when handling them. Slides of macrophytes can also be useful as part of a reference collection. Index the reference collection using an index card box file. Group the cards, but have a separate card for each species, detailing identification features and information available.

A collection of 'difficult' specimens, to which reference may need to be made for quality assurance purposes, should be compiled either as an integral part of the reference collection or as a supplementary collection in its own right.

4.7.3 Preservation of macrophytes

Refer to Bridson and Forman (1992) and Moore (1986) for full details of equipment and methods.

The majority of macrophytes are suitable for pressing. The identified macrophyte specimen should be floated in a shallow tray containing water. A piece of smooth, shiny, drying paper or good quality cartridge paper should be placed under the macrophyte and then lifted from the tray. Fine adjustments of the macrophyte position are then made, so that all attributes can be seen. A pipette and brush may facilitate such adjustments. A second piece of labelled (use a waterproof marker/pencil) drying paper is placed on top of the macrophyte. Layers of newspaper/other absorbent paper are placed either side of the macrophyte and paper sandwich, and the whole thing is placed in a flower press, which is then shut. Use a corrugate between layers if available to add air circulation and hence aid drying — keep the press size small if no corrugates are available. Pressure should be evenly applied. The press should be stored in a dry atmosphere. The absorbent paper should initially be changed after 24 hours and then after a further 48 hours. Regularly change the absorbent paper until the macrophyte specimen is completely dry.

Charophytes can be kept by preserving them in 4% formalin or by drying (Moore 1986, pp. 26–28). For mucilaginous species, the drying sheet should be covered with a piece of waxed paper or polythene so the specimen does not stick to the drying paper in the plant press.

4.7.4 Storage and identification

Macrophyte specimens collected in the field will persist in good condition for several days if placed in plastic bags or lidded tubes **without** additional water. Blowing into the bag before it is sealed prevents crushing and may help to preserve samples. The sealed bag/tube stops the specimen drying out; adding no extra water means the specimen does not turn into an unidentifiable soggy mass. On return to the laboratory store the samples in a refrigerator.

The exception to this is filamentous algae. A sample should be placed with a small amount of water into a labelled tube, ensuring that there is a large air space above the water. As above, the tube should be stored in a refrigerator on return to the laboratory. A few drops of ethanol may extend the period for identification but may extract the chlorophyll (formalin should not be used). Alternatively, Lugol's iodine may be used to preserve the sample (Jones 1979).

Identify specimens one at a time as it is extremely important that the correct macrophyte is recorded under the correct survey and abundance class.

In a filamentous algae sample the dominant species should be recorded. For example, a filamentous algae mass consisting mainly of *Cladophora* will also contain small amounts of other species, but only the *Cladophora* needs to be recorded.

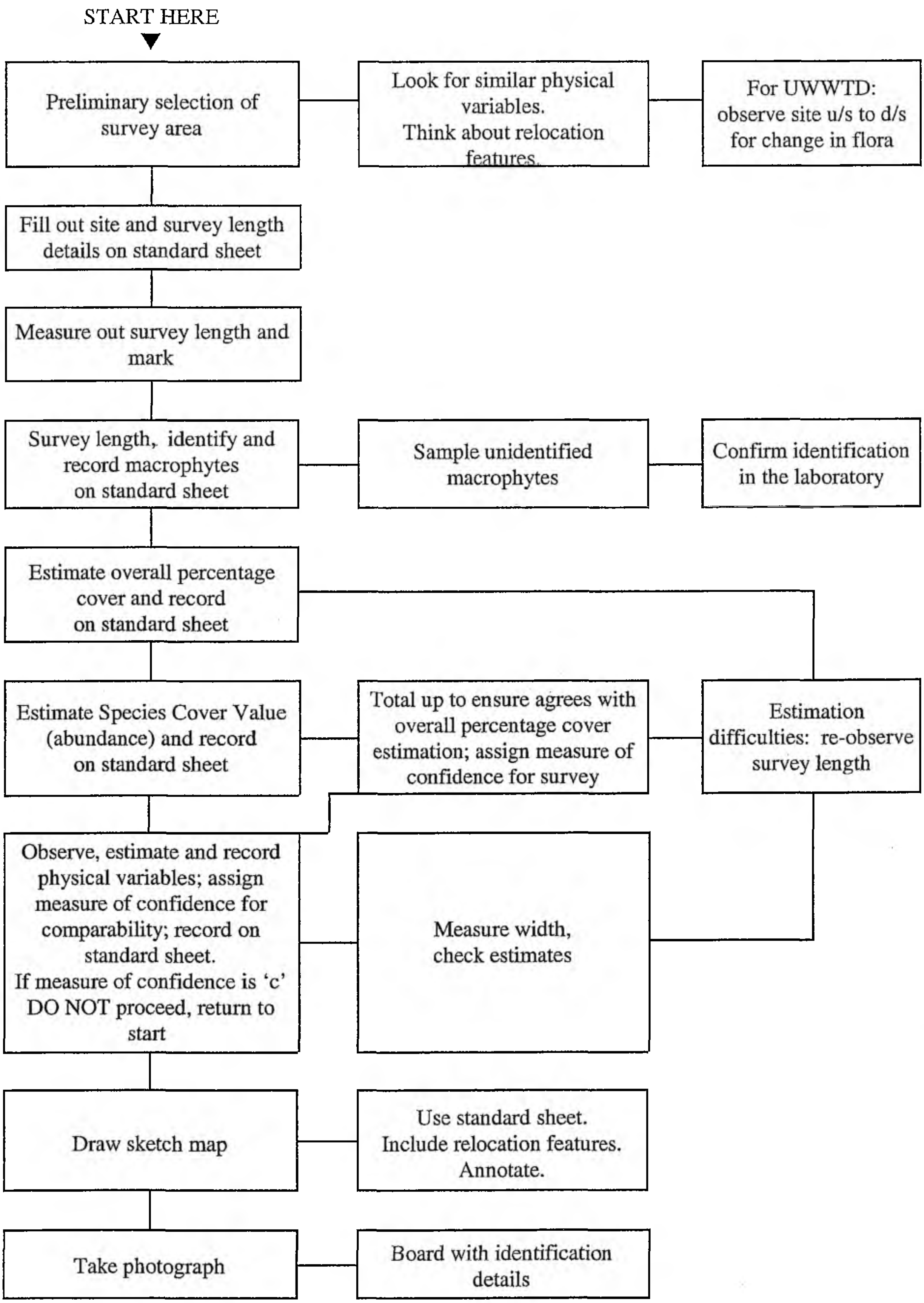


Figure 3 Summary Macrophyte Survey Flow Chart

5 MTR DATA ANALYSIS

This Chapter describes how to use the macrophyte data collected to calculate a Mean Trophic Rank score for the survey and how to express the confidence in that score. It also provides guidance on data storage.

5.1 Calculating Mean Trophic Ranks

Selected, usually common, aquatic macrophytes have been assigned a number from 1 to 10 according to their tolerance/preference for enriched or un-enriched waters; this is the Species Trophic Rank (STR). The STR for each selected species can be found on the standard record sheet and the species checklist in Appendix 5.

Mean Trophic Ranks (MTR) are to be calculated for 100m survey lengths only. All scoring species should be included in the calculation of the MTR, but **non-scoring species should be excluded**. MTR scores are calculated as follows:

1. For all scoring species recorded, multiply the Species Trophic Rank (STR) by the Species Cover Value (SCV) to give a Cover Value Score (CVS) for each scoring species.

Example:	Scoring species	STR		SCV		CVS
	Enteromorpha sp(p)	1	×	1	=	1
	Cladophora agg.	1	×	1	=	1
	Nuphar lutea	3	×	1	=	3
	Lemna minor	4	×	7	=	28
	Potamogeton pectinatus	1	×	1	=	1
	Mentha aquatica	-	×	(2)	=	-
	Zannichellia palustris	2	×	1	=	2
	Amblystegium riparium	1	×	1	=	1
	Ranunculus fluitans	7	×	7	=	49
TOTAL				20		86

2. Add up all the numbers in the CVS column.
3. Add up the numbers in the SCV column associated with scoring species only. Do not include non-scoring species in this calculation.
4. Divide the total score for the CVS by the total for the SCV and multiply by 10 to give the Mean Trophic Rank (MTR): MTR = (sum of CVS ÷ sum of SCV) × 10
   In the above example: MTR = (86 ÷ 20) × 10 = 43.0
5. Present MTR to ONE decimal place only.

NB Where no scoring species are present in the survey length, there is no MTR score for the survey. An MTR value of zero may be recorded for data archiving purposes but this value must not be used to indicate trophic status.

5.2 Assigning a measure of confidence to the MTR

A selected number of scoring taxa on the species checklist (Appendix 5) are highlighted in bold type (and prefixed with a '➢' symbol). The number of these 'highlighted' or 'bold' species present in a survey length is used to assign a measure of confidence in the MTR score (Environment Agency 1996a, Holmes 1996).

To determine the confidence with which the MTR score can be considered, assign one of the following suffixes:

- a - > 8 **highlighted (bold)** taxa are present
- b - 5–8 **highlighted (bold)** taxa are present
- c - < 5 **highlighted (bold)** taxa are present.

Record this in the space provided on the species checklist (Appendix 5).

The rationale behind this suffix of confidence is that (i) these 'highlighted' species are particularly reliable indicators of trophic status and (ii) the greater the number of reliable indicator species present, the greater the reliability of the resulting MTR. Although evaluation of the MTR methodology has found no conclusive evidence to support the first premise, there is evidence that the MTR score may be more reliable when more highlighted species are present (Dawson at al 1999b). It is therefore recommended that the use of this suffix of confidence be continued as an interim measure. Achievement of a suffix of 'a' or 'b' will certainly lend confidence in the results; but achievement of a 'c' suffix may not necessarily mean that the result is inaccurate. In all cases, emphasis should be placed on obtaining information from as many sources as possible and on drawing conclusions using the balance of evidence.

5.3 Assessment of confidence in the data

The MTR score is suffixed by the three measures of confidence assigned based on site comparability (I, II, III: see 4.6.12), survey conditions/typicality (A, B, C: see 4.5.7) and the number of highlighted taxa (a, b, c: see 5.2), to enable an immediate interpretation of likely confidence in the data.

For example:	U/S	MTR	=	43.0 (I, B, b)
	D/S	MTR	=	14.7 (I, A, b)

Thus, it is clear that both sites are physically comparable; that site survey accuracy at the upstream site was affected to a moderate degree by some management, adverse turbidity or the like, but not at the downstream site; and that 5–8 highlighted taxa were recorded.

It is strongly recommended that surveys with a suffix of confidence of 'III' and/or 'C' should not be used for interpretation of trophic status, as there is sufficient cause for concern that either the MTR does not represent the prevailing trophic status at the site and/or any differences in MTR between sites may be due to factors other than a difference in trophic status. In such cases, effort should be made to look for and survey an alternative site or pair of sites. To minimise this circumstance, care should be taken both in the initial selection of the survey lengths, to avoid selection of unsuitable lengths (see Box 2), but also upon arrival at site for established survey lengths, to confirm that MTR is an appropriate method to use (see Box 3).

5.4 Data storage

Data should be stored on a standard computer database. All data should be handled in a standard meticulous manner. Remember your entry may be checked at random by someone else at any time. Accuracy of data entry is of prime importance. It is recommended that the initials of the data-archiver and the date of archive are entered onto the field sheet, to provide an 'audit trail' for quality assurance purposes.

> ***Quality assurance***
>
> Enter macrophyte data regularly — mistakes are less likely to be made if there is not too much data to be entered at once so the operator does not become desensitised to the process.
>
> Check each data entry is correct before starting the next entry.
>
> Establish a system of filing and keep to it, so if a discrepancy is discovered at a later time it can be easily checked (for example, file the original survey sheets in site order u/s to d/s for each river). Retaining field sheets after archiving on the database also allows the hard copy to be presented as evidence if required in the future.

6 INTERPRETATION OF MTR RESULTS

This chapter provides guidance on presenting and interpreting results from MTR surveys. It focuses mainly on interpretation for UWWTD purposes but also considers other applications.

6.1 Interpretation for the purposes of the UWWTD

6.1.1 General

The aim of using the MTR in the context of UWWTD monitoring should be borne in mind at all times when interpreting MTR results and preparing these results for presentation. This aim is to provide evidence of:

i) eutrophication impact on macrophyte communities in order to support designation of reaches as SA(E); and

ii) the specific impact of qualifying discharges on such reaches.

MTR assessments are only one aspect of the considerations needed to identify SA(E)s and all other supporting data should be evaluated before final recommendations are made regarding potential candidates. These data can include overall percentage macrophyte cover, other biological data (such as TDI/DQI), chlorophyll data and chemical data. Account should be taken of known management practices and impacts on the site(s).

6.1.2 Presentation of Results

Results from MTR monitoring undertaken for UWWTD purposes will comprise a number of surveys over a period of years at each site (usually 3 or 4 surveys over 4 years) and a minimum of two sites per QD, one upstream and one downstream. Each group of surveys carried out at the same time, ie within a few days but at different sites, is termed a 'set' of surveys, for the purposes of this guidance.

Information from MTR surveys should be presented in a concise, accurate and consistent format. To achieve this, a standard approach to data presentation and interpretation should be adopted. For UWWTD purposes, this approach should comprise the following elements.

1. Present results as actual MTR scores (to one decimal place), together with the percentage downstream change in MTR downstream of a qualifying discharge. Present results for each set of surveys; do not average results to obtain a mean for the period monitored.

2. Interpret each set of results in terms both of trophic status and of the significance of impact from the QD, by use of a standard set of 'rules', a set of standard descriptors being used to describe the resulting conclusions. The 'rules' and descriptors are given below in Section 6.1.3.

3. Assess the consistency of results in the same reach on different sampling occasions to verify that any eutrophication impact observed is ongoing and consistent, and that anomalous data are not due to anomalous weather conditions or conditions of atypical flow. Do not, however, compare individual scores between different years.

6.1.3 Standard Approach to Interpretation of MTR Results

Underlying Principles

This approach is based upon a standard set of decisions with the following underlying principles:

i) Sites with MTR scores of more than 65 are unlikely to be eutrophic. However, these sites could be at risk of becoming eutrophic and the MTR should be compared with that expected in an un-impacted, physically similar reach.

ii) Sites with MTR scores of less than 25 are badly damaged by either eutrophication, organic pollution, toxicity or are physically damaged.

iii) Sites with MTR scores between 25 and 65 are likely to be either eutrophic or at risk of becoming eutrophic. However, as the MTR may be limited purely by the physical nature of the site, the MTR should be compared with that expected in an un-impacted, physically similar reach. This is probably most relevant to those sites with MTRs between 45 and 65 (see Table 1); below an MTR of 45, it is likely that the site is impacted by eutrophication. Sites with a high number of species which are unimpacted may often have MTR scores in the range 45–65. This is due to the large number of species with STRs of 4–6 which biases the MTR to 40–60. Sites which are obviously unimpacted (eg >20 species present) should be recognised as such within this category.

iv) A downstream change in MTR is deemed to be significant if the difference is at least 4 MTR units or 15%.

A predictive framework of the MTRs to be expected in un-impacted rivers of different physical types, although currently in the early stages of development, is currently not yet available. To assist operational decisions until such a framework is available, reference may be made to two sources of information.

Firstly, broad comparisons can be made using MTR data from other local sites with similar altitude, geology and flow characteristics but lower nutrient concentrations. The importance of undertaking more comprehensive catchment surveys in this respect is emphasised in 2.4.3 and such sampling strategies are to be encouraged as good practice.

Secondly, reference may be made either to the provisional MTR values mapped by Holmes (1995) and/or to the top 10% of MTR values recorded for each of the River Community Types used by English Nature (EN), Scottish Natural Heritage (SNH) and the Countryside Council for Wales (CCW) to classify rivers for SSSI designation on the basis of their macrophyte communities (Table 1). Both the MTRs mapped by Holmes (1995) and those summarised in Table 1 are derived from the same set of macrophyte surveys, using data courtesy of EN, SNH and CCW. Although they are not directly comparable with MTR values from standard MTR surveys, being derived using a different survey methodology and (in the case of those mapped by Holmes 1995) an earlier version of the MTR, they can give useful information to put MTR scores into broad context. It should be emphasised, however, that they should **not** be used to predict the expected MTR in an un-degraded system. This is for two reasons. Firstly, the River Community Types represent characteristic assemblages of species not of physical river habitat parameters. The 'general description' does, however, give an indication of the type of river in which each assemblage typically occurs, given in terms not only of the physical characteristics of the river (eg altitude, flow and geology) but also in some cases in terms of the trophic status. Thus, trophic status is integral to the River Community Type classification. Secondly, although Holmes' MTR data set may be biased towards rivers of high conservation value with relatively low pollution impact, it does cover a broad spectrum of trophic states. Table 1 should not, therefore, be used as a template of the expected norm in an un-degraded system, but rather as a 'pointer' towards what may be un-impacted by eutrophication for a particular River Community Type. Two examples may illustrate this. If the MTR recorded at an upland site is significantly lower than the mean or upper 10% of MTR values shown for comparable River Community Types in Table 1 (eg the MTR for a Type VIII site is 25, compared to the mean value of 70.6 or the upper 10% value of 86.4 shown in Table 1), then this would indicate that the MTR is lower than expected for an un-degraded reach of the same physical type. If, however, the MTR recorded at a lowland site of Type IV is comparable with the mean shown for this type in Table 1 (eg the MTR for the site is 41, compared to the 'typical' mean value of 40.0), then this only indicates that it is typical for Type IV communities, not that the site is un-impacted by eutrophication nor that the MTR is un-repressed especially as the mean of the upper 10% of values for this site is 61.0.

To be deemed significant, a downstream change must exceed that which may arise from either natural variation in the MTR, the inherent variability in the methodology, and/or human error. Analysis of MTR results from throughout the UK indicates that 4 MTR units or 15% is an appropriate threshold, this being twice the mean variation in MTR during the survey season and greater than the median difference due to variation between surveyors (Dawson et al 1999b). Hence, a reduction in the MTR of greater than 4 units or 15% downstream of a QD means that there is a significant detrimental impact. Reductions of less than 4 units or 15% may mean that there has been a significant impact but that it cannot be demonstrated by the use of the MTR. However, it is also important to consider the actual MTR scores impacted. A 15% change at the higher end of the scale (> 65) will indicate communities likely to become eutrophic, whereas a 15% change at the lower end (< 25) of the scale will usually represent a change from eutrophic to hyper-eutrophic. In general, it can be assumed that a change at the higher end of the scale represents a tendency to become eutrophic while a change at the lower end of the scale is simply a measure of increased eutrophication.

Table 1 MTR scores summarised according to river community types **(DO NOT USE THIS TABLE TO PREDICT MTRs)**

RIVER COMMUNITY TYPE [1.]	GENERAL DESCRIPTION [1.]	Mean MTR [2.]	Mean of top 10%	No. of samples [2.]
I	Lowland rivers with minimal gradients. Predominantly in south and east England, but may occur wherever substrates are soft and chemistry enriched	34.0	40.8	49
II	Rivers flowing in catchments dominated by clay	32.9	42.9	429
III	Rivers flowing in catchments dominated by soft limestone such as Chalk and Oolite	40.2	47.3	136
IV	Rivers with impoverished floras, confined to lowlands or eutrophic systems	39.5	58.2	361
V	Rivers of sandstone, mudstone and hard limestone catchments in England and Wales, with similar features to those of Type VI	47.6	65.3	559
VI	Rivers predominantly in Scotland and northern England in catchments dominated by sandstone, mudstone and hard limestone; substrates usually mixed coarse gravels, sands and silts mixed with cobbles and boulders	46.2	59.6	258
VII	Mesotrophic rivers where fine sediments occur with boulders and cobbles, so a mix of bryophytes and higher plants is typical; often downstream from Type VIII communities	52.9	75.0	97
VIII	Oligo-mesotrophic, fast-flowing, rivers, where boulders are common and bryophytes typify the plant assemblages; intermediate, and often between, Types IX and VII	68.1	82.0	537
IX	Oligotrophic rivers of mountains and moorlands where nutrient and base levels low; bedrock, boulders and coarse substrates dominate	68.8	86.2	70
X	Ultra-oligotrophic rivers in mountains, or streams flowing off acid sands; substrates similar to Type IX but often more bedrock	83.0	95.5	327

1. Revised classification of Holmes et al (1998) from the version previously published in the SSSI selection guidelines (Nature Conservancy Council, 1989).
2. MTRs calculated from 1km sites, each split into consecutive 500m lengths, using a 5-point abundance scale, in England, Scotland and Wales. Data are unpublished but were prepared initially for the purposes of Holmes (1995). Macrophyte data are courtesy of Scottish Natural Heritage, English Nature and Countryside Council for Wales.

Standard 'rules': use of flowchart 'decision trees'

The trophic status of each site and the magnitude of impact of QDs should be assessed by following the steps below, these steps referring to the flowcharts shown in Figures 4 and 5. The flowcharts must only be used in conjunction with the information contained within this manual and not used in isolation.

The flow charts are devised for use where there is one site upstream of a qualifying discharge and one site downstream. If there is more than one site upstream or downstream, then the same overall principles and descriptors of trophic status and significance of impact apply.

The steps are as follows.

1. Determine the standard 'descriptor' for the trophic status of each site, using the Stage I 'decision tree' flowchart (Figure 4). These descriptors are in given in the shaded boxes and are each assigned a reference number. This descriptor is intended to determine whether a reach is a suitable case for submission as a potential candidate for SA(E) designation.

2. a) If the final descriptor is 1 or 2 there is no significant evidence for eutrophication and the MTR cannot be used to support the designation of a SA(E).
   b) If the final descriptor is 3–5 then the evidence can be used to support the designation of a SA(E) and the Stage II flow chart should be used to assess the impact of the qualifying discharge (proceed to 3 below).
   c) If the final descriptor is 6 then there is little evidence from the MTR which can be used to support the designation of a SA(E) but other evidence may prove useful in supporting the designation.

3. For reaches including sites with standard descriptors 3–5:

   For each pair of sites upstream and downstream a qualifying discharge calculate the percentage change in MTR downstream compared to upstream of the discharge.

   NB % change = $(Y - X)/X \times 100$, where X and Y are the MTR values at the upstream and downstream sites respectively. Downstream reductions in MTR will thus always be denoted by a negative value.

   Determine whether the discharge is having a significant impact by using the Stage II 'decision tree' flow chart (Figure 5) to determine the standard descriptor for the significance of the impact, these descriptors again being given in the shaded boxes with a reference number.

For each QD/potential candidate SA(E) there will be a number of sets of results (3–4 over 3 years for most). The above steps should be followed separately for each set of survey results thereby producing a descriptor of trophic status for each survey and a descriptor of the significance of the QD impact for each set of surveys.

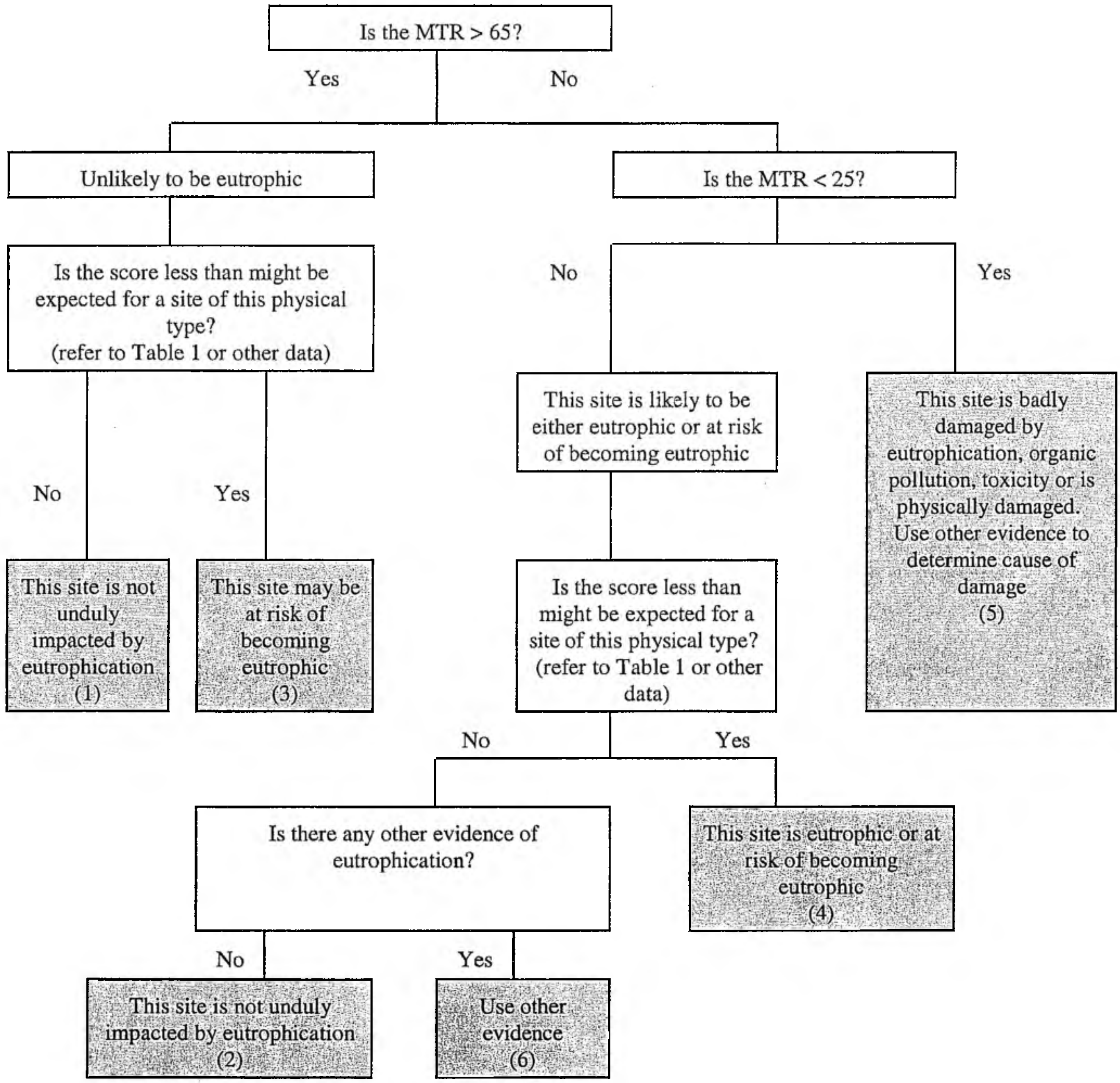


Figure 4 Interpretation of MTR results, Stage I 'decision tree': Is the site impacted by eutrophication?

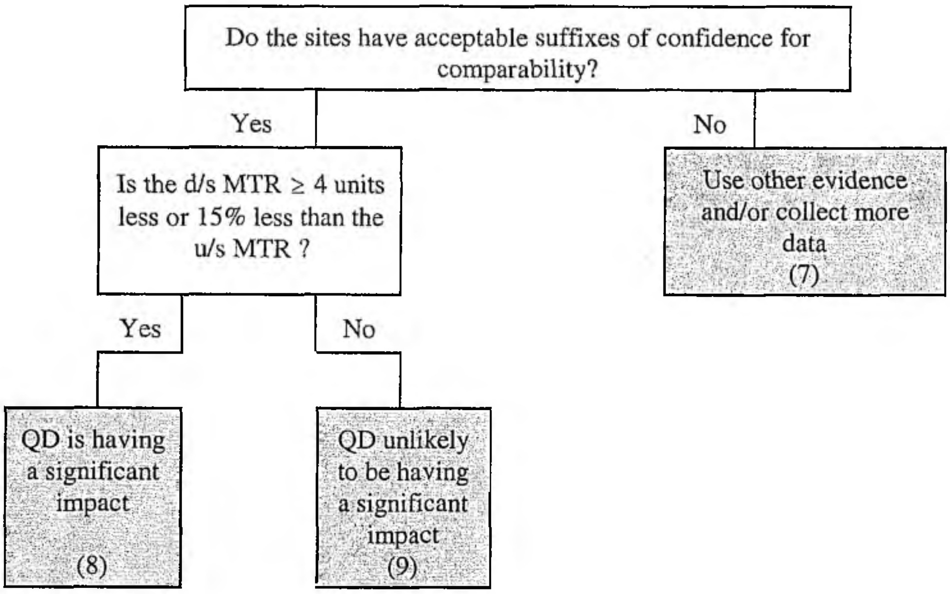


Figure 5 Interpretation of MTR results, Stage II 'decision tree': Is there a significant downstream impact from the qualifying discharge?

Caveat

On some rivers, MTR scores are inherently low. This does not necessarily mean that the site is eutrophic. If the baseline MTR for these rivers is low and other biological monitoring programmes do not show that eutrophication is occurring, then a change within the rules set out above may indicate a tendency to eutrophication. Loss of species with high STR values may indicate that the site is not yet eutrophic but is about to become so.

6.2 Interpretation for other purposes

Interpretation of the MTR for other purposes follows the same essential principles as outlined in section 6.1. This is important as it ensures that a standard approach is taken to the assessment of riverine habitats on a national basis.

Please also refer to Section 2.4, for an outline of the applications listed below.

6.2.1 Non-qualifying point-source discharges

Although not yet proven for this application, it can reasonably be assumed that the MTR will perform in a similar manner to nutrient inputs from non-qualifying point-sources as it does to inputs from QDs.

The aim is to look for change in the MTR score downstream of a potential impact. Interpretation of data is as for the UWWTD, the main difference being that there is unlikely to be a QD in the vicinity of the survey. The term QD is thus replaced by 'potential source of pollution' or PSP for non-UWWTD purposes.

If a significant change cannot be demonstrated then it does not mean that the potential impact is not having an effect. It may be that the change is at an early stage and may not be detectable by the MTR system, or it may be that other physical and chemical factors are masking the impact of increased nutrient-loading on the macrophyte community.

6.2.2 Non-point source nutrient inputs

Interpretation of data is as for non-qualifying point-source discharges, except the PSP can be a wide area. This application is largely untried (2.4.2, 3.2.2).

6.2.3 Catchment studies

This refers to studies undertaken to gain an overview of the trophic status of catchments, in order to prioritise those areas which would benefit most from further investigation or nutrient reduction effort. This includes studies undertaken for the purposes of eutrophication management strategies and catchment/river-basin management plans.

When interpreting MTR data, the following broad principles should be adopted.

- Actual scores must not be compared between sites unless they are physically (confidence in survey of I or II) and chemically similar.
- Trophic status should be interpreted on a site-by-site basis, using the flow-chart given in Figure 4 to determine the standard descriptor for each site. Results may be mapped by assigning a number, symbol or colour to the standard descriptors.
- Similarly, the significant impacts can be mapped using the 3 standard descriptors in the flow-chart given in Figure 5. The magnitude of downstream changes in MTR can be compared.
- Although MTR scores may be placed into arbitrary groups for mapping purposes, such maps must only be used to illustrate MTR scores: no inference should be made to trophic status, which should be based on a site-by-site interpretation as specified above. To avoid mis-interpretation of such maps, their use is discouraged.

6.2.4 Temporal changes in trophic status

Although this application is untried, it is recommended that in the interim, the same essential principles for interpretation of data be adopted as for spatial changes in trophic status. Thus, the trophic status of a site should be determined by means of the standard descriptors provided in Figure 4, and a change in MTR over time must be at least 4 units or 15% for it to be deemed significant in terms of trophic status. This should mean that the change is greater than that which may be expected from natural background variation and from sampler error. When assessing the response of a river to nutrient-reduction measures, however, it is important to also interpret temporal changes against the baseline variation for that river, as established over a number of years prior to the commencement of nutrient reduction.

6.2.5 Future development

The limitations of the MTR, in terms of the complexity of interacting factors by which it may be influenced, are recognised (Dawson et al 1999b). The guidance given above regarding interpretation of data is thus the best available at the current time, given these limitations. Further research and development to assess the effect of geology, altitude, flow type and other environmental variables, is necessary before further refinement of the method can be made. This may lead to the establishment of benchmark MTR values for river types which could be used to assess the extent of deterioration from the typical value. Nationwide comparisons of eutrophication impact may then be made.

6.3 Interpretation of species diversity

Species diversity (the number of scoring species) should not be used by itself as an indicator of trophic status. The relationship between species number and phosphate concentration is not linear (Figure 6). Although phosphate concentration may determine, to some extent, the maximum diversity possible at a site, this potential may not be realised in many cases due to other factors.

In certain circumstances, however, species diversity may prove helpful as a supplementary measure of the community response to trophic status, in addition to the MTR, but should only be used with extreme caution. Although no prescriptive 'rules' can be given, refer to Figure 6 and bear the following indicative guidance in mind:

- a low or intermediate diversity may be recorded at any phosphate concentration;
- a high diversity is unlikely to be recorded at either very high concentrations of phosphate or very low concentrations;
- at any phosphate concentration, the 'envelope' shape of the relationship between diversity and phosphate concentration means that a wide range of diversities may be recorded;
- diversity should only be used to support the interpretation of MTR results in those situations where both a downstream change in diversity, or a temporal change at the same site, is very marked <u>and</u> the influence of factors other than a change in trophic status is deemed insignificant.

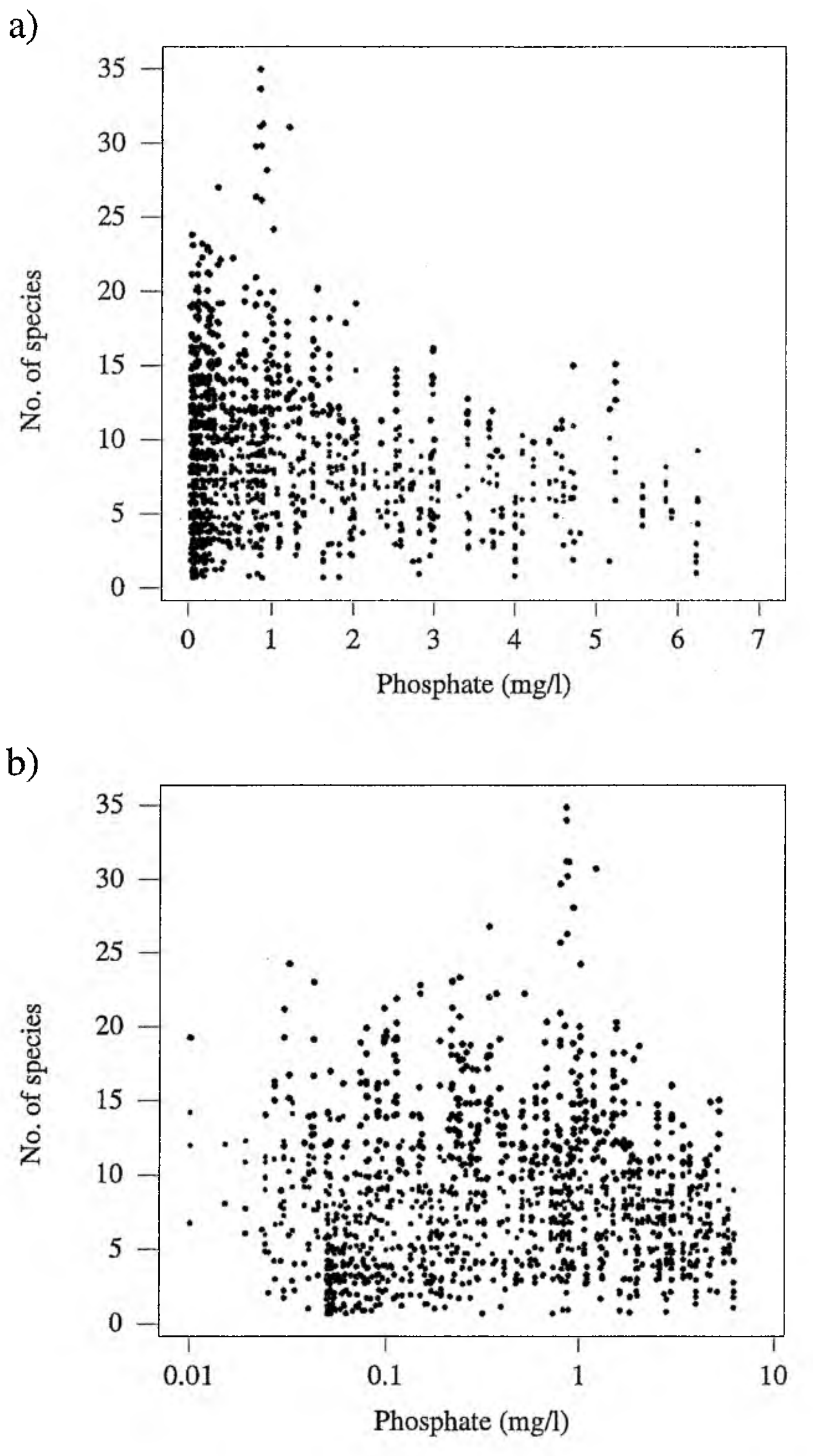


Figure 6 Relationship between the number of scoring species and the phosphate concentration. (Figure 39, R&D Technical Report E39, Dawson et al 1999b).

6.4 Interpretation of overall percentage cover values

Overall percentage cover is, by itself, of little use in terms of assessing trophic status. There is no relationship between overall percentage cover and phosphate concentration. It is still a useful parameter to record, however, for the following three reasons.

- In many cases it acts as a double check on the percentage covers given to individual scoring species.
- In some cases, eutrophication may cause a change in overall percentage cover, and if so is worthy of note.
- Excessive growth of macrophytes, resulting in very high overall percentage cover values, can in itself result in problems to users of rivers, giving rise to complaints, and may impact on river management functions. Where such complaints or impacts arise, it is important to establish whether the excessive growth is due to eutrophication, or to other factors. Where it is due to eutrophication, then this clearly constitutes an 'undesirable disturbance' in UWWTD terms.

Where a marked change is recorded, determine whether this is a result of a change in trophic status by establishing to which key species the change in overall cover and the change in MTR can be attributed. If the key species is/are the same, then the change in overall cover is likely to be due to a change in trophic status. If so, then this is worthy of mention when reporting results. Where the change is a very marked increase in overall percentage cover, such that it may give rise to complaints from river users (either on aesthetic grounds or as a result of physical disturbance to use of the river), then this clearly constitutes an 'undesirable disturbance' in terms of the definition of eutrophication given in the UWWTD.

Perhaps the most notable example of this relates to situations where the key species is *Cladophora*. If an increase in overall percentage cover and a decrease in MTR is due mainly to an increase in percentage cover of *Cladophora*, then it may be deduced that the increase in overall percentage cover is a manifestation of eutrophication.

7 QUALITY ASSURANCE

This chapter highlights the main sources of error and variation in MTR survey results, and the need for a quality assurance procedure to reduce these. It then gives detailed guidance on quality assurance for MTR surveys, including training requirements and protocols for audit surveys.

7.1 Introduction

7.1.1 Sources of error and variability

Surveyor error and differences between surveyors

The most common sources of surveyor error and variation between surveyors are:
- differences in estimates of macrophyte cover;
- incorrect identification of macrophytes, especially of *Ranunculus* species and some species of bryophytes;
- missed species, where present only in isolated small ($\leq$25cm^2) patches;
- differences in interpretation of which specimens are 'in' and 'out' of the channel;
- errors in accurately locating the survey length.

All can be reduced by provision of adequate training, correct application of the method and adoption of quality assurance measures.

At the survey stage, particular attention should be paid to strict adherence of the survey methodology, taking adequate time to estimate percentage cover values, retaining representative samples of 'difficult' specimens for subsequent confirmation of identification, looking out for small patches of macrophytes, ensuring that the sketch map is accurate, and ensuring that the survey length is located correctly.

At the data interpretation stage, allowance for surveyor variation is made in the guidance given in Chapter 6: the MTR score must change by at least 4 units or 15% for it to be deemed significant in terms of trophic status, this being greater than the median difference which may be expected from inter-surveyor variation (6.1.3). Individual species percentage cover estimates should be approached with care due to their semi-quantitative nature. Only gross changes in percentage cover should be considered worthy of note and it should be remembered that the estimation of SCVs can vary between surveyors by up to 2 units (abundance classes) for the majority of the time.

Background variation in MTR

The MTR score varies within the survey season, with a mean difference of 7.5% between surveys undertaken at the same site but at different times within the season (Dawson et al 1999b). Allowance for within-season variation is made in the guidance on survey timing and interpreting results: surveys in consecutive years at the same site should be undertaken at the same time of the survey season every year (3.3.1), and MTR must change by at least 4 units or 15% for it to be deemed significant, this being twice the mean difference to be expected from within-season variation (6.1.3).

Other temporal changes in the MTR score which may arise, for example due to natural cycles of plant growth, river conditions or river management works, are allowed for by use of the suffix of confidence in the survey (4.5.7).

The MTR may also be influenced by the size of the river, its slope, substrate size, underlying geology and the altitude of its source, as well as by nutrient status or other chemical determinands. Allowance for this source of variation is made in the guidance provided on selecting survey lengths and interpreting results: site comparability is one of the factors to be taken into account when selecting survey lengths (Box 2) and survey lengths should only be compared if they are physically similar (as expressed by the suffix of confidence, 4.6.12).

7.1.2 The need for quality assurance

It is important that the sources of variation outlined above are reduced so that maximum possible confidence can be placed in the accuracy, or 'quality' of survey results. This is normally achieved by application of a quality control procedure, the aim of which is to minimise unavoidable errors in carrying out the survey methodology; set quality targets and determine whether these are being met; and provide a means for restoring quality if targets are not met.

Most standard quality control systems which are used for other biological surveys and chemical analyses, such as control charts, ring sorts and resorting of samples, are not appropriate for macrophytes. Macrophyte surveys produce data directly from a field survey. No samples are taken, except for those required for identification or confirmation purposes. Re-surveys alone are probably not sufficient, as they occur after the surveys have been undertaken and real changes may have occurred in the interim. In addition, the de-limitation of the 'sample unit' available to the re-surveyor (the upstream and downstream limits of the survey length and the definition of the 'channel') is itself integral to the methodology and open to error.

The requirement for MTR surveys is therefore for a system of quality assurance, aimed at minimising errors. Several aspects of MTR surveys can undergo quality assurance to a greater or lesser degree. These include:

- operation of the method
- number of species
- abundance categories
- overall percentage cover
- identification
- database entry accuracy

In addition, relocation of survey lengths can be audited if required. This is recommended where survey results at any one site are to be analysed from more than one visit (such as for UWWTD monitoring) and the surveys undertaken by different a surveyor(s) on each occasion.

Quality assurance measures relating to many of the above are described as an integral part of the implementation of the survey and the calculation of the MTR (shaded boxes in chapters 4 and

5). These MUST be adhered to as a very minimum. It is strongly recommended, however, that the following additional measures are also implemented to ensure the highest possible quality of data is maintained throughout the application of the method. These include:

- training (7.2)
- audit surveys (7.3)
- inter-calibration exercise (7.4)
- data storage (7.5).

7.2 Training

Each member of staff must have a personal training record with details of all courses and on-the-job training received.

All surveyors should receive basic safety training. This may also include boat handling courses and First Aid training if appropriate.

In addition to this basic training, training must be provided in the specific areas of MTR survey methodology, MTR calculation, database entry and interpretation of results.

7.2.1 New staff

The areas in which new staff must be trained are:

Identification

A basic macrophyte identification course is needed before any surveys are undertaken. This course should cover all the commonly occurring macrophytes found in the locality. The new staff member, or a surveyor transferred from another geographical region, should look through, and become familiar with, the reference collection and identification guides.

Method

New staff members must read this manual and accompany an experienced surveyor for field training. Resulting data and identification should be checked by another surveyor. Until the supervisor is confident of the proficiency of the new surveyor, the surveyor should accompany other surveyors for on-the-job training. All new members of staff should attend the annual method training and quality assurance exercises.

It is very important that new members of staff are made aware of the importance of the accuracy required when making estimates of percentage cover values for individual species. Regular training exercises should be carried out throughout the season.

Data handling

This should take the form of in-house training by an experienced member of staff.

7.2.2 Maintaining skills

Minimum requirements

Macrophyte surveys can only be carried out during the summer months, resulting in a lengthy gap between consecutive survey seasons. To improve and maintain survey quality, each surveyor must undergo the following essential training:

(i) each surveyor must read (or be trained in) this manual at the start of each survey season; and
(ii) each year, each surveyor must either undertake a set minimum number of MTR or other macrophyte surveys (the suggested minimum is five surveys per year), or attend a training course at which MTR surveys are undertaken (this may be the 'refresher' course described below).

At the beginning of the survey season, surveyors who did not achieve the minimum requirement of (five) surveys in the previous year should not undertake further surveys until they have received MTR training. (Note that this is referring to the number of surveys not the number of pairs/sets of surveys up- and downstream QDs. Refer to the glossary for the definition of survey.)

Annual 'refresher' course

It is recommended that all surveyors attend an annual 'refresher' course in survey techniques and identification skills each year. This course may contribute to the minimum training requirement cited above. The course should be held at the start of, or early in, the survey season and should encompass all aspects of the survey method with particular attention to the subjective estimates.

The course should include:
- an overview of how to carry out an MTR survey;
- at least one standard MTR field survey with discussions at each stage, including the identification features of macrophytes found in the survey length;
- a exercise designed to estimate percentage cover of macrophyte species in the field and to compare estimates between surveyors;
- an identification exercise whereby each surveyor individually identifies a set of specimens provided and the identifications are then discussed so everyone learns from the exercise.

7.2.3 On-going training

It is recommended that more experienced staff from each area office should attend an advanced macrophyte identification course(s). This should cover macrophytes which are 'difficult' to identify to species level, such as some *Ranunculus*, fine-leaved *Potamogeton*, *Callitriche* and Bryophyte species. These staff will then be able to help with identification confirmation.

7.2.4 Exceptions

The only exceptions to the above recommendations regarding training are where, in a team of three or more, a member of the team is assigned tasks not requiring macrophyte identification skills, ie assigned to neither the assessment of macrophyte presence/cover nor the drawing of the sketch map. Tasks to which this team member may be assigned include, for example, the recording of macrophyte presence/cover (not the assessment), the assessment of the physical characteristics of the site and/or handling of the boat. In such a case, there is no requirement for this team member to be trained in macrophyte identification. This is subject, however, to at least two members of the team being fully trained in all aspects of the methodology. All members of the team should be trained in the general operation of the method.

7.3 Audit surveys

7.3.1 General

Audit surveys (repeat surveys for quality assurance purposes) are useful in monitoring consistency of performance between surveyors/survey teams, highlighting mis-application or mis-interpretation of the method, and thus providing an additional means to minimise errors. Two re-survey protocols are described below — Level 1 and Level 2 — each delivering a different level of specification in terms of quality assurance, and each requiring a different resource investment. The choice of which level to adopt will depend on the purpose of the survey programme, the resources available and the cost-benefit/value-for-money. If a sufficient number of surveys are to be carried out within a survey season, then it is possible to assign some surveys to Level 1 and other to Level 2 audit protocol, as appropriate. The audit programme for each level can be undertaken separately but concurrently.

The level of audit protocol adopted for each primary survey should be indicated by marking the relevant box on the field sheet. The standard field recording sheet should also be used for audit surveys and data should be archived and analysed as for primary surveys.

To avoid confusion with re-surveys undertaken as a result of action triggered by the QA process itself, re-surveys undertaken for audit purposes are hereafter termed 'audit surveys'. For simplicity, any reference below to 'primary surveyor' or 'auditor' may refer either to a single surveyor or a team led by a 'principal surveyor' (3.3.8, 7.3.6).

7.3.2 Level 1 Audit Protocol: high specification, 'very best practice'

This protocol provides a high specification quality assurance system which aims to ensure that quality never drops below a set threshold. It incorporates: an objective assessment of consistency; quality targets; and actions to take when targets are not met to ensure that a very high quality is maintained. It is most suitable in circumstances where the purpose of the survey demands maximum quality of results and where resources and time allow. In other circumstances it may be neither practical nor represent value-for-money.

The procedure to follow is described in Box 9. Note that the last primary survey of the season needs to be sufficiently early to allow the entire last batch of surveys to be re-surveyed before the end of the season if necessary. The criteria for differences between primary and audit surveys to be deemed as being significant (point 5 in Box 9) are based partly on the results collated as part of the evaluation of the MTR (Dawson et al 1999b) and partly on levels of difference found in a small study of re-surveys in Anglian Region of the Agency (Environment Agency 1996b), which found that 87% of scoring taxa were recorded within one SCV and 94% within two SCV. Criterion (v) is set at a level which is greater than the median difference between audit and primary surveys analysed by Dawson et al (1999b) and is assumed to be outside the normal deviation when sampled correctly by the same surveyor on different occasions.

7.3.3 Level 2 Audit Protocol: moderate specification, best practice

The aim of this protocol is to improve the quality of the results by improving the quality of the surveyor; with a 'safety net' to rectify gross mistakes. This provides a lower specification of quality assurance than the Level 1 protocol, incorporating: an indication of consistency; quality targets; and measures to both minimise identified errors being repeated in future surveys and to correct gross errors in previous surveys. It is most suitable in circumstances where maximum quality of results are preferred but resources and time do not allow Level 1 protocol; and/or where the purpose of the survey does not demand Level 1 protocol. All efforts should be made to comply with this level of QA protocol.

The procedure to follow is given in Box 9. The option to inform the primary surveyor prior to the audit survey means that if necessary the surveys can take place on the same day ('double-surveys'), which eliminates errors arising out of changes occurring in the time lapse between surveys. If survey length relocation is to be included as an element to be audited, then the primary surveyor and auditor must not confer about demarcation of the survey length limits; if not included, then conferring is allowed, thus eliminating a further source of error. Under no circumstances, however, is conferring or discussion allowed on any other element of the survey.

7.3.4 The auditor

The site **must** be relocated accurately. It is, therefore, essential that the auditor has a copy of the sketch map pointing out distinguishing features.

The auditor must be able to go out at short notice. Surveying is weather dependant, so although basic timing of the surveys is planned the actual timing may differ.

The auditor must be experienced both in identification skills and the method. The auditor must have attended an approved training course in the standard methodology.

More than one person will probably be needed to audit a site, depending on its physical nature.

Audit surveys may be undertaken by either an internal or an external auditor

Internal quality surveyor

This is an experienced member(s) of staff from within the same organisation. The advantage of internal quality surveyors is that they will have been trained to use the method in the same way as the primary surveyors and so this should lead to more consistency in the resulting audit; thus reducing the possibility that any differences recorded are due to different interpretations of the method. The disadvantages arise from conflicts of interest between the audits and other biology work. It is preferable if some of the audits are done by surveyors from other teams, to improve national consistency.

External quality surveyor

This is an external expert. This may be difficult to organise, however, especially as the audits need to be done at short notice. There may also be problems in ensuring the external surveyor is using the method in the same way as internal staff. They must, however, have read this manual and attended an approved MTR training course prior to commencement of the audit surveys. It may be necessary for an internal member of staff who is not involved with any MTR surveys to organise the audit surveys and to liaise between the primary surveyors and the external auditor.

7.3.5 Circumstances where an audit survey is not appropriate

Sites where the physical nature of the survey length makes it difficult to undertaken an adequate survey (eg the river bed is obscured due to turbidity/depth of water, or access is difficult) may be excluded from the selection of surveys to audit. The same methodology should always be used for the audit survey as was used in the primary survey. In cases where the survey length has become unsuitable for survey in the intervening period between the primary and audit survey, then the audit survey should not be undertaken. If sufficient surveys remain in the 'batch', then an alternative survey may be selected for audit.

7.3.6 Staffing level

A minimum of double-staffing is recommended as good practice (3.3.8). Where surveyors work consistently together in the same team, the 'surveyor-unit' to be assessed for QA purposes is the team, under the direction of the principal surveyor, rather than the individual surveyors. Similarly, an audit survey can be undertaken by a team, under the direction of a 'principal surveyor'. In such cases, read 'team' in place of 'surveyor', 'primary surveyor' or 'auditor'. Where the composition of the team is not consistent, then the 'surveyor-unit' to be assessed is the principal surveyor.

Box 9 Audit procedure

1. At the start of the survey season a surveyor not involved with the primary surveys is appointed as auditor (see 7.3.4). The auditor is provided with details of the planned survey programmes, including anticipated dates and a copy of the survey site sketch map and location description for each site. If the site has not been surveyed before then the map and description can be forwarded to the auditor immediately upon completion of the primary survey.

2. Before the survey programme begins, the auditor selects, at random, those surveys to be audited. One survey is selected for each 'batch' of 10 consecutive surveys (or part thereof), with a minimum of one survey audited per season for each primary surveyor/survey team [1].
   Level 1 protocol: the primary surveyor is not informed of the selection.
   Level 2 protocol: the primary surveyor may be informed of the surveys selected.

3. Immediately upon completion of the primary survey, the surveyor(s) informs the auditor that the survey has been completed and is available for audit. The auditor must then undertake a re-survey of the site as soon as possible after the primary survey, to reduce differences due to external factors (eg heavy rain, reduced flows, management work such as weed cutting, seasonal changes in abundance, level of identification possible due to presence or absence of flowers/fruiting bodies). If conditions remain unchanged an audit survey may be done up to two weeks from the time of the primary survey, although this may not be acceptable where floating species are present. The most reliable results will be obtained if audit surveys are done as soon as possible.
   Level 1 protocol: the audit survey is undertaken without the knowledge of the primary surveyor(s) and there is no conferring or discussion about the site/survey until that batch of primary surveys is completed.
   Level 2 protocol: the primary surveyor is informed immediately after the audit survey that the audit has taken place.

4. Audit survey results are compared with those of the primary survey and the differences identified. Parameters to compare are: number of species, species names, SCVs, MTR and overall percentage cover.
   Level 1 protocol: this takes place immediately after the batch of surveys has been completed, but not before.
   Level 2 protocol: this takes place immediately after the audit survey, regardless of whether the batch of surveys has been completed.

5. Differences between primary and audit surveys are deemed significant if any of the following criteria are met: [2]
   i) 3 or more species missed, recorded or identified incorrectly [3]
   (or 4 or more missed, if 20 or more scoring species on the primary survey)
   ii) 10% or more of the SCV values differ by 3 or more SCV units [3]
   iii) 20% or more of the SCV values differ by 2 or more SCV units [3]
   iv) difference of more than 15 percent points in overall percentage cover

continued.....

Box 9 Audit procedure *(.....continued)*

v) difference of more than 4 in the MTR (either direction).

6. If significant differences are found then the primary surveyor and auditor meet together to determine the reason(s) for the differences and whether they are attributable to surveyor error.

   Possible reasons for differences due to surveyor error include:
   - survey relocation
   - missed species
   - mis-identification of species
   - mis-recording of species
   - errors in estimation of abundances
   - mis-calculation of the MTR.

   Factors other than surveyor error which may cause differences include:
   - management work taking place between the two surveys
   - poor survey conditions on one of the surveys
   - natural changes in the macrophyte community, eg following a spate
   - change in nutrient concentration in the water (with the possible exception of species such as *Cladophora*, however, the flora is unlikely to respond to nutrient changes in the short time between primary and audit surveys).

   In some cases, the determination of the reason(s) may be relatively easy, for example: mis-identification of a specimen retained in a herbarium or re-calculation of the MTR. In other cases, it may be resolved by analysis of the sketch map and/or a return to the site: for example, confirmation of whether a particular isolated specimen was in the survey length or just outside; or confirmation of a dominant and abundant macrophyte. Reference to the suffix of confidence in the survey and to weather conditions between the two surveys should help eliminate, or otherwise, differences being due to changes in the physical conditions of the site. In yet other cases, however, determination of the reason(s) for the difference(s) may be impossible. In these cases, a re-survey may be required with both surveyors in attendance (this may be required anyway if using the Level 1 protocol). If the dispute is about % cover estimates, a qualified third party referee may be useful.

   Do not assume that the audit survey is necessarily the more correct of the two surveys being compared. The audit only identifies differences not errors. Only when inconsistencies are analysed by both surveyors, with a third party referee if necessary, can it be determined where actual errors lie.

7. Action is taken according to Table 2. Note that in cases of error by the primary surveyor, all surveys in the batch must be re-surveyed for the Level 1 protocol but only selected (if any) re-surveys are required for the Level 2 protocol.

1. Refer to the definition of survey in the glossary. Individual surveys are audited, not pairs/sets of surveys up- and downstream QDs.
2. It is recommended that these criteria are reviewed nationally in the future.
3. Scoring species only. Records of free-floating species must be treated with care as these can move into or out of the survey length between the primary and audit survey.

Table 2 Reasons for mismatch between primary and audit survey, with suggested actions

REASON	ACTION REQUIRED	EXAMPLE(S)
Changed conditions in the time lapse between the primary and audit survey.	The comparison is rendered invalid for quality assurance purposes. Another survey can be selected from the remainder of the batch for audit, if following the Level 2 protocol and the batch is not complete. Otherwise the batch of surveys must be deemed as not to have been subject to quality assurance. In either case, greater effort should also be placed in future into reducing the time lapse to a minimum.	Examples include where changes in flow conditions have either up-rooted macrophytes or caused a change in their abundance; or where species (eg *Enteromorpha*) have been washed from the site.
Survey length relocation error.	Unless the difference can easily be resolved by a return visit to the site by both primary surveyor and auditor, the comparison is rendered invalid for quality assurance purposes (actions as above). Greater effort should be placed in future on producing and using accurate location instructions.	
Error by the auditor.	The comparison is rendered invalid for quality assurance purposes (actions as above). Take measures to ensure that mistakes are not repeated in either future surveys or audits.	
Difference in MTR due to mis-calculation of the MTR on the part of the primary surveyor. *	Validate the MTR calculation on all surveys in the batch (for Level 1 protocol) or all previous surveys in the batch (for Level 2). Take extra care in future to ensure that such mistakes are not repeated (computerised calculation of MTR values will assist in the latter, especially if compared with hand-calculated values immediately after data input).	
Survey error(s) on the part of the primary surveyor.	Action required depends on level of audit protocol adopted. Level 1 protocol: Re-survey all surveys in the batch, compare with primary surveys and agree which results are correct. Level 2 protocol: Identify previous surveys in the batch which are likely to be in gross error due to the same mistake and validate the survey results. 'Gross error' is defined as an error which could significantly change the interpretation of trophic status. Validation may be achieved in the office/laboratory, or it may require the primary surveyor and auditor returning to the site without having to do a full re-survey. In other cases, where validation cannot be achieved with confidence, a full re-survey may be necessary. Verify or agreeing the 'correct' record and take steps to ensure that the mistake is not repeated in future surveys.	Examples of cases where re-surveys may be considered for Level 2 protocol: (1) if the error is a mis-identification, then only those surveys in the batch where the 'mis-identified' species has been recorded in abundance may need to be re-surveyed; (2) if the error is solely in abundance estimates, but relates specifically to, say, the estimation of a sparse but widespread cover of *Cladophora*, then the only surveys which may need re-surveying are those where a sparse widespread cover of *Cladophora* were present.

* *Note: as errors solely due to mis-calculation do not require re-survey, verify the accuracy of the calculation before investigating further/other reasons for the MTR difference, but remember that a difference in MTR could be due to both mis-calculation and some other reason(s).*

7.4 Inter-calibration exercise

It is recommended that each surveyor should attend an inter-calibration exercise every year. This is designed to assess the level of consistency between surveyors and has some similarities to a Level 2 audit survey, but involves more surveyors and the surveys are always done simultaneously on the same day. The inter-calibration may be between individual surveyors within a team, or between survey-teams. Preferably, the exercise should be held once some macrophyte surveys have been completed rather than at the beginning of the survey season, although it can be combined with the annual refresher training. The difference between the refresher training and the inter-calibration exercise is that the former includes instruction in the method (even if only an overview of the key points), whereas the inter-calibration need only involve a field comparison of surveys. If the two are combined, then the inter-calibration can form the final part of the field training session.

All participants meet in the field, with one person having overall responsibility. A 100m survey length is then selected and marked, and each surveyor individually surveys this length. The exception to this is where surveyors consistently work together in teams, whereby the survey-team is the surveyor-unit being assessed. In these cases, individual teams survey the site under the direction of the usual 'principal surveyor'. Abundance of individual macrophyte species is recorded using the 9-point Scale C. Although the drawing of a sketch map is optional for assessment purposes, at least one sketch map should be drawn per exercise, with relocation features for future reference. Results of the surveys should not be discussed until after all surveys have been completed.

Data should be analysed afterwards to determine the level of consistency between surveyors. A report should be produced on the data, identifying inconsistencies and recommending measures to address them, eg any areas where further training is needed. As with the Level 2 QA protocol, this inter-calibration allows for an on-going assessment of the errors involved in all aspects of the surveying.

Where possible, different types of site should be surveyed in this manner. It should be remembered that results from turbid and/or deep water sites will not be as accurate as those where the bed is visible at all times.

7.5 Database verification

This is the element of the methodology most amenable to quality control. The 'data entry unit' being assessed may be either a team or individuals, depending on the number of surveys entered onto the database. It is helpful if the date of archive is marked on each sheet upon completion of data input: this reduces the chance of records being input twice by mistake, and facilitates the audit process. Where the quality of data input by individuals is assessed, it is imperative that the initials of the individual are also marked on the survey sheet.

At intervals throughout the survey season a random selection of the surveys entered onto the database should be examined by two members of staff. A recommended number of surveys is 10% of the total or at least 20. The entries should be checked for accuracy by ensuring that the paper field sheets and the database entries match. If any of the surveys are not accurately recorded the survey data for all surveys input prior to the validation date should be examined and re-entered or amended from the field record sheets if necessary (unless already verified). Field sheets corresponding to verified data entries should be marked with a symbol, eg a 'V', to indicate that they have been verified and the date of verification. Once the season is over, and either all data entries have been verified or no errors have been found in the random sample(s) of entries, then data for that season can be deemed to have been accurately entered and need no longer be subject to quality control in subsequent seasons. Paper records of survey results may need to be retained, depending on the purpose of the survey.

7.6 Survey length selection

If there is any cause for concern that a survey length is not in an appropriate place to detect changes in MTR due to a change in nutrient concentration (or other factors) then due consideration should be given to changing the survey length within the parameters set out in the section for survey length selection (3.3.3 and Box 2). If this is not possible then discussion should be held to establish a better sampling site.

Survey length selection is essentially governed by a common sense approach to using the guidelines set down in this manual. If for any reason the survey length does not produce results which are useful for the intended purpose it may not be possible to use this method for an assessment of the trophic status of the water at that site and consideration should be given to using other methods.

8 MTR BEST PRACTICE CHECKLIST

This chapter summarises best practice for MTR surveys, as a "do" (✔) and "don't" (✘) checklist.

8.1 Uses of MTR

✔ Use the MTR to assess the trophic status of rivers for the purposes of the EC Urban Waste Water Treatment Directive, including the designation of SA(E)s and monitoring the effects of phosphate removal.

✔ The MTR may be used for the assessment of other point-sources of nutrients, but is not yet proven for applications other than UWWTD monitoring.

✘ Do not make direct comparisons of MTR values between rivers of different physical types.

✘ Do not use the MTR to assess the trophic status of standing waters, canals (unless the water flow is constant in one direction) or rivers with a tidal influence.

8.2 Survey planning

✔ Use both MTR and DQI if possible.

✘ Do not use MTR (or DQI) in isolation. Use all biological and chemical information available to decide if a site is a suitable candidate for designation as an SA(E) under the UWWTD.

✔ Undertake whole catchment or sub-catchment studies wherever possible, to place MTR scores in context.

✔ Continue to carry out MTR surveys after the introduction of nutrient reduction measures, including upstream and possibly 'control' sites to establish the natural background variation.

✔ At each site, carry out at least one survey per year for a minimum of three years, between mid-June and mid-September (inclusive), at the same time of the season each year.

✔ Select the survey site and survey length with care, selecting physically comparable sites where possible and taking into account the various factors which may influence the survey results.

✔ Plan surveys so that they can be undertaken by a minimum of two operators.

✔ Collect background information on geology, altitude and slope. Find out whether river management work is scheduled or has been undertaken, and whether pollution incidents have occurred.

8.3 Survey methodology

✔ Check equipment list before departure to field sites and follow health and safety guidelines at all times.

✘ Do not survey during or after periods of high flow, flooding or management operations, nor in windy conditions, turbid water (unless normal) or periods when boat traffic is heavy.

✔ Check that the survey length is correctly located and paced measurements are accurate.

✔ Cross the survey length every 2.5m in a zig-zag manner, surveying the whole river width if possible.

✘ Do not guess percentage cover estimates. Estimate on the basis of observation, using one of the methods of estimation recommended in this manual.

✔ Use a grapnel, glass-bottomed bucket and/or an underwater TV camera where appropriate, to aid observation and identification of macrophytes. Take particular care to look for small patches of macrophytes.

✘ Do not use grapnel samples to estimate percentage cover: only record percentage cover based on observation of plants *in situ*.

✔ Identify macrophytes to species level where possible. Take representative specimens of 'difficult' species back to the laboratory for confirmation of identification. Maintain a herbarium.

✘ Do not record macrophytes overhanging, but neither attached nor rooted in the channel.

✔ Record physical variables, make a sketch map and take a photograph.

✔ Fill in all the details on the survey sheet at the time of the survey, except for the SCV total, CVS total, MTR score and data-archiving details. Assign a measure of confidence in the survey (A, B or C) and in the physical comparability of sites (I, II or III) before leaving the site or shortly afterwards.

✘ Apply extreme caution to MTR results assigned a suffix of confidence of 'C' and/or 'III'.

8.4 Data analysis

✔ Calculate MTR to one decimal place, using scoring species only.

✔ Assign a measure of confidence in the MTR score, based on the number of highlighted species.

✘ Do not use surveys with a suffix of confidence of 'III' and/or 'C' to interpret trophic status.

✔ Check that data entered onto computer are correct.

8.5 Interpretation of results

✔ Use the underlying principles, 'decision trees' and standard descriptors set out in this manual, as a guide to interpretation of MTR results.

✔ Compare MTR results with relatively un-impacted reaches on the same river to indicate what MTR scores should be achieved. Set results into a catchment context.

✔ Use data from other sources to support your case.

✘ Do not expect the MTR to provide a measure of trophic status *per se*: it can only measure change from an un-impacted site and degradation downstream of a pollution impact.

✘ Do not use species diversity or overall percentage macrophyte cover by themselves as indicators of trophic status, although they may prove a useful supplementary measure in certain circumstances.

8.6 Quality assurance

✔ Ensure that all staff involved in surveys have undergone the statutory training courses and annual refresher courses, and that for all the macrophyte species likely to be encountered, there is at least one member of staff who can identify them accurately.

✘ Do not undertaken MTR surveys unless you have attended a training course on the method and until you have read this manual.

✔ Adopt one of the two recommended audit protocols: Level 2 is the recommended minimum.

✔ Carry out audits of selected sites on a random basis within 2 weeks of the primary survey.

✔ Take action immediately if audit mismatch criteria are met. Discuss significant differences between primary and audit surveys to establish the causes for differences and re-visit or re-survey the site if necessary to confirm the reasons for the differences (or as required by the audit protocol).

✘ Do not assume that the audit survey is always more correct than the original.

✔ Check all results, database entries and audit survey results on a regular basis, and take appropriate action if errors are discovered.

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9 REFERENCES

(see Appendix 3 for identification guides and preservation manuals)

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APPENDICES

Appendix 1 Rare plants

Red Data Book ** and Nationally Scarce* macrophytes associated with running waters:

Potamogeton acutifolius **	Sharp-leaved Pondweed
*Potamogeton nodosus***	Loddon Pondweed
*Callitriche hermaphroditica**	Autumnal Water-starwort
*Carex aquatilis**	Water Sedge
*Ceratophyllum submersum**	Soft Hornwort
*Eleocharis acicularis**	Needle Spike-rush
*Myriophyllum verticillatum**	Whorled Water-milfoil
*Nymphoides peltata**	Fringed Water-lily
*Potamogeton coloratus**	Fen Pondweed
*Potamogeton compressus**	Grass-wrack Pondweed (listed as a priority species in the UK Biodiversity Action Plan)
*Potamogeton filiformis**	Slender-leaved Pondweed
*Potamogeton friesii**	Flat-stalked Pondweed
*Potamogeton praelongus**	Long-stalked Pondweed
*Potamogeton trichoides**	Hairlike Pondweed
Luronium natans	Floating-leaved Water-plantain (listed in Annexes II & IV of the EC Habitats Directive, Appendix I of the Bern Convention and as a priority species in the UK Biodiversity Action Plan)
Callitriche truncata	Short-leaved Starwort

Appendix 2 Foreign invasive plant species

Several foreign species of macrophytes have become established in the British Isles. Some of which are considered to be nuisance vegetation as they have spread rapidly and compete with other native species. While surveying for river macrophytes it takes little time to note the presence of these species. The species to look out for are:

River species:

The following species are assigned a Species Trophic Rank. Their presence can affect the distribution/abundance of natives.

Canadian Pondweed	*Elodea canadensis*
Nuttall's pondweed	*Elodea nuttallii*
Water-fern	*Azolla filiculoides*
Sweet-flag	*Acorus calamus*

Others to note:

Australian Swamp Stone-crop	*Crassula helmsii*
Cape Pondweed	*Aponogeton distachyos*
Beggar-ticks	*Bidens frondosa*
Large-flowered Water-thyme	*Egeria densa*
Curly Water-thyme	*Lagarosiphon major*
Lupin	*Lupinus nootkatensis*
Pink Purslane	*Montia sibirica*
Winter Heliotrope	*Petasites fragrans*
	Petasites japonicus
Canary Grass	*Phalaris canariensis*
Swamp Meadow-grass	*Poa palustris*
Tape-grass	*Vallisneria spiralis*
Purple Iris	*Iris versicolor*
Indian Balsam	*Impatiens glandulifera*
Orange Balsam	*Impatiens capensis*
Giant Hogweed	*Heracleum mantegazzianum*
Japanese Knotweed	*Polygonum (Reynoutria) japonica*
Monkey flower	*Mimulus guttatus*

Information from SERCON lists and pers comm. Nigel Holmes.

Appendix 3 Identification guides and preservation manuals

Macrophyte Preservation:

Moore JA (1986) *Charophytes of Great Britain and Ireland.* BSBI Handbook No 5.

Bridson D & Forman L (1992) *The Herbarium Handbook Revised Edition.* Royal Botanic Gardens, Kew (ISBN 0 947643 45 1).

Books specific to Water Plants:

Haslam SM, Sinker CS & Wolsey PA (1982) *British Water Plants.* Field Studies Council, Nettlecombe, Taunton, Somerset.

Spencer-Jones D & Wade M (1986). *Aquatic Plants: A guide to recognition.* ICI Professional Products, Fareham, Surrey.

Ranunculus sp:

Holmes NTH (1979) A Guide to Identification of Batrachium Ranunculus Species of Britain. Chief Scientist's Team Notes No 14. Nature Conservancy Council, Shrewsbury.

Potamogeton sp:

Preston CD (1996) *Pondweeds of Great Britain and Ireland.* Botanical Society of the British Isles Handbook No. 8.

Course guides:

Holmes NTH. A Guide to Identifying British Aquatic Plant Species - accompanying guide to field course. (obtained through attending field course)

General books/keys:

Blamey M & Grey-Wilson. *Illustrated Flora of the British Isles.*

Clapham AR, Tutin TG & Moore DM (1989) *Flora of the British Isles.* CUP 3rd ed. (key)

Clapham AR, Tutin TG & Warburg EF (1981) *Excursion Flora of the British Isles* (3rd ed). Cambridge University Press. (key)

Garrard I & Streeter D (1983) *The Wildflowers of the British Isles.* Macmillan, London.

Keble-Martin W (1976) *The Concise British Flora in Colour.* Edbury Press and Michael Joseph.

Rich TCG & Jermy AC (1998) *Plant Crib.* BSBI, London, 392pp.

Rose F (1981) *The Wildflower Key.* Warne, London. (key)

Stace C (1997) *New Flora of the British Isles.* Cambridge University Press, 1130pp. (key)

Sedges:

Jermy AC, Chater AO & David RW (1982) *Sedges of the British Isles.* BSBI Handbook No 1.

Grasses:
Hubbard CE (1968) *Grasses* (2nd ed). Penguin.

Bryophytes:

Watson EV (1968) *British Mosses and Liverworts.* CUP, 495pp.
Smith AJE (1990) *The Moss Flora of Britain and Ireland.* CUP.
Smith AJE (1991) *The Liverworts of Britain and Ireland.* CUP.

Charophytes:
Allen GO (1950) *British Stoneworts (Charophyta).* Haslemere Natural History Society.
Moore JA (1986) *Charophytes of Great Britain and Ireland.* BSBI Handbook No 5.

Algae:
Belcher H & Swale E (1976) *A Beginner's Guide to Freshwater Algae.* HMSO, London, 47pp.
Bellinger EG (1980) *A Key to Common British Algae.* Institution of Water Engineers and Scientists, London, 94pp.
Pentecost A (1984) *Introduction to Freshwater Algae.* Richmond Publishing Co., Surrey, 247pp.

BSBI handbooks are available for various macrophyte groups, eg umbellifers, willows and docks.

Appendix 4 Equipment suppliers

This list is provided for illustrative purposes only. It includes examples of current suppliers at the time of writing, but may **NOT** include all suppliers of the equipment. No responsibility is accepted for the reliability or otherwise of the information given, nor any recommendation attached to any of the equipment listed.

1. Underwater TV camera Model FM-1000

The camera runs on a 12 volt battery - without the use of the light this provides power for approximately 3 hours, with the light on continuously the power lasts for only 0.5 hours. Spare batteries will therefore be needed, and the camera should be switched off when not in use. No further accessories are provided by the suppliers - cable reels which will be necessary can be bought from hardware/DIY stores.

Price Feb 1997 £2,200 + VAT for a complete system.
Available from Bansho Co Ltd, The Grainger Suite, Dobson House, Regent Centre, Newcastle, NE3 3PF. Tel 0191 284 2213, Fax 0191 284 0222. Contact Mr David Liddle.

2. Optical Range Finder

These are available from York Survey Supply Centre Tel: (01904) 692723. Short range models are no longer available from this outlet.

Model code 43130: This has a range of 10 to 75 m which would be suitable for the widest rivers only. Cost £45.96 + VAT.

Optional case for range finder (code 43132) £11.44 + VAT.

3. Glass-bottom bucket

No supplier for these has been found. It is suggested that you approach local chandlers to ask if they could supply anything suitable. Organisations with access to a workshop may be able to get one made.

Basically, the glass-bottom bucket can be of any size (bucket, swing-bin, washing-up bowl). The item should preferably be opaque. A section is removed from the base leaving a 2–5 cm lip on to which a piece of perspex or similar is sealed. The perspex is probably best placed on the outside of the bucket so that the lip provides some support as once pushed under water there will be some pressure which could dislodge the perspex if placed inside the bucket. Putty or some kind of bathroom sealant can be used to attach the perspex. The bucket should be stored with the perspex uppermost to avoid scratching the surface; the bucket should not be used for carrying field equipment.

4. Bathyscope

Obtainable from SEAC Direct, Sheffield.
Tel. 0114 270 1234 Fax. 0114275 8855
Price £35.95 (although a minimum order of £50.00).

Appendix 5 Standard record sheets

The following record sheets are appended:

Survey record sheet
Species checklist
Standard Sketch Map sheet, 100m survey length
Standard Sketch Map sheet, 500m survey length
Reference sheet for % cover estimates
Reference sheet for substrata

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MTR MACROPHYTE SURVEY FIELD RECORD SHEET

Site details

River name ____________________ Site name ____________________

NGR top ____________________ NGR bottom ____________________

Survey details

Date ___/___/___ Start time ___:___ Surveyor(s) ____________

Percentage cover scale: 9 point, **C** ☐ 5 point, **A** ☐ Survey length: 100 m ☐ 500 m ☐

Wadeable ☐ Non-wadeable ☐ Boat ☐

Overall percentage cover ___ % Measure of confidence of typicality ____
(survey distorted by: A <25%, B 25-50%; C >50%)

Physical Records

Record the actual estimated percentage for each of the following **AND** Record 1 = <5%, 2 = 5 - 25% and 3 = >25% in the boxes below for comparison with previous surveys (optional for the latter)

Width (m) <1 __% ☐ 1-5 __% ☐ >5–10 __% ☐ 10–20 __% ☐ >20 __% ☐

Depth (m) <0.25 __% ☐ 0.25–0.5 __% ☐ >0.5–1.0 __% ☐ >1.0 __% ☐

Substrata Bedrock __% ☐ Boulders/Cobbles __% ☐ Pebbles/Gravel __% ☐

Sand __% ☐ Silt/Clay __% ☐ Peat __% ☐

Habitats Pool __% ☐ Run __% ☐ Riffle __% ☐ Slack __% ☐

Shading Left bank None __% ☐ Broken __% ☐ Dense __% ☐

Right bank None __% ☐ Broken __% ☐ Dense __% ☐

Water clarity Clear __% ☐ Cloudy __% ☐ Turbid __% ☐

Bed stability Solid/Firm __% ☐ Stable __% ☐ Unstable __% ☐ Soft/Sinking __% ☐

Photograph identification facing downstream? ☐ facing upstream? ☐

____

____

Sketch map completed? ☐ Diatom sample taken (optional)? ☐

Measure of confidence for comparability of survey lengths (I >75%; II 50-75%; III <50%)

1) Site name ____________________ Site name ____________________
Measure of confidence ____

2) Site name ____________________ Site name ____________________
Measure of confidence ____

3) Site name ____________________ Site name ____________________
Measure of confidence ____

Comments

____

River name ______________________ **Site name** ______________________________

NGR top __________________ **NGR bottom** __________________ **Survey date** __ / __ / __

Macrophyte Records: Scoring species

SPECIES NAME	STR	SCV	CVS	SPECIES NAME	STR	SCV	CVS
				RUNNING TOTALS:			
Batrachospermum sp(p)	6			Polytrichum commune	10		
Hildenbrandia rivularis	6			Racomitrium aciculare	10		
Lemanea fluviatilis	7			➤ **Rhynchostegium riparioides**	5		
➤ **Vaucheria sp(p)**	1			➤ **Sphagnum sp(p)**	10		
➤ **Cladophora agg.**	1			Thamnobryum alopecurum	7		
➤ **Enteromorpha sp(p)**	1						
➤ **Hydrodictyon reticulatum**	3			➤ **Azolla filiculoides**	3		
				Equisetum fluviatile	5		
➤ **Chiloscyphus polyanthos**	8			Equisetum palustre	5		
Jungermannia atrovirens	8						
➤ **Marsupella emarginata**	10			➤ **Apium inundatum**	9		
➤ **Nardia compressa**	10			➤ **Apium nodiflorum**	4		
Pellia endiviifolia	6			➤**Berula erecta**	5		
Pellia epiphylla	7			➤ **Callitriche hamulata**	9		
➤ **Scapania undulata**	9			➤ **Callitriche obtusangula**	5		
				➤ **Ceratophyllum demersum**	2		
Amblystegium fluviatile	5			➤ **Hippurus vulgaris**	4		
➤ **Amblystegium riparium**	1			➤ **Littorella uniflora**	8		
Blindia acuta	10			Lotus pedunculatus	8		
Brachythecium plumosum	9			➤ **Menyanthes trifoliata**	9		
Brachythecium rivulare	8			Montia fontana	8		
Brachythecium rutabulum	3			➤ **Myriophyllum alterniflorum**	8		
Bryum pseudotriquetrum	9			➤ **Myriophyllum spicatum**	3		
Calliergon cuspidatum	8			➤ **Myriophyllum spp indet**	6		
Cinclidotus fontinaloides	5			➤ **Nuphar lutea**	3		
Dichodontium flavescens	9			➤ **Nymphaea alba**	6		
Dichodontium pellucidum	9			➤ **Nymphoides peltata**	2		
Dicranella palustris	10			Oenanthe crocata	7		
➤ **Fontinalis antipyretica**	5			➤ **Oenanthe fluviatilis**	5		
➤ **Fontinalis squamosa**	8			Persicaria amphibia	4		
➤ **Hygrohypnum luridum**	9			Potentilla erecta	9		
➤ **Hygrohypnum ochraceum**	9			➤ **Ranunculus aquatilis**	5		
➤ **Hyocomium armoricum**	10			➤ **Ranunculus circinatus**	4		
Philonotis fontana	9			Ranunculus flammula	7		
TOTALS				TOTALS			

Continued....

River name ______________________ Site name ______________________________

NGR top __________________ NGR bottom __________________ Survey date __/__/__

Macrophyte Records: Scoring species, continued

SPECIES NAME	STR	SCV	CVS	SPECIES NAME	STR	SCV	CVS
RUNNING TOTALS:				RUNNING TOTALS:			
➤ **Ranunculus fluitans**	7			➤ **Elodea nuttallii**	3		
Ranunculus hederaceus	6			Glyceria maxima	3		
Ranunculus omiophyllus	8			➤ **Groenlandia densa**	3		
➤ **Ranunculus peltatus**	4			➤ **Hydrocharis morsus-ranae**	6		
➤ **R. penicillatus pseudofluit.**	5			Iris pseudacorus	5		
➤ **R. penicillatus penicillatus**	6			➤ **Juncus bulbosus**	10		
➤ **R. penicillatus vertumnus**	5			➤ **Lemna gibba**	2		
➤ **R. trichophyllus**	6			➤ **Lemna minor**	4		
Ranunculus sceleratus	2			➤ **Lemna minuta/minuscula**	3		
➤ **Ranunculus spp indet**	6			➤ **Lemna trisulca**	4		
Rorippa amphibia	3			Phragmites australis	4		
➤ **Rorippa nast.aquat./offic.**	5			➤ **Potamogeton alpinus**	7		
Rumex hydrolopathum	3			➤ **Potamogeton berchtoldii**	4		
➤ **Veronica anagallis-aquat.**	4			➤ **Potamogeton crispus**	3		
➤ **Veronica catenata**	5			➤ **Potamogeton friesii**	3		
➤ **Veronica anag./cat. indet.**	4			➤ **Potamogeton gramineus**	7		
Veronica scutellata	7			➤ **Potamogeton lucens**	3		
Viola palustris	9			➤ **Potamogeton natans**	5		
				➤ **Potamogeton obtusifolius**	5		
Acorus calamus	2			➤ **Potamogeton pectinatus**	1		
Alisma plantago-aquatica	3			➤ **Potamogeton perfoliatus**	4		
Alisma lanceolatum	3			➤ **Pot. polygonifolius**	10		
Bulbochoenus maritima	3			➤ **Potamogeton praelongus**	6		
➤ **Butomus umbellatus**	5			➤ **Potamogeton pusillus**	4		
Carex acuta	5			➤ **Potamogeton trichoides**	2		
Carex acutiformis	3			➤ **Sagittaria sagittifolia**	3		
Carex riparia	4			➤ **Schoenoplectus lacustris**	3		
Carex rostrata	7			➤ **Sparganium emersum**	3		
Carex vesicaria	6			➤ **Sparganium erectum**	3		
Catabrosa aquatica	5			➤ **Spirodela polyrhiza**	2		
Eleocharis palustris	6			Typha latifolia	2		
➤ **Eleogiton fluitans**	10			Typha angustifolia	2		
➤ **Elodea canadensis**	5			➤ **Zannichellia palustris**	2		
TOTALS				**TOTALS**			
				MTR (∑ CVS/∑ SCV) x 10			

Continued....

River name ______________________ **Site name** ________________________________

NGR top ________________ **NGR bottom** ________________ **Survey date** __/__/__

Macrophyte Records: Non-scoring species

SPECIES NAME	SCV	SPECIES NAME	SCV
Thick diatom scum		Blue-green algal scum	
Filamentous green algae		Sewage `fungus'	
Stigeoclonium tenue		Callitriche species indeterminate	
Glyceria notata/fluitans/declinata		Potamogeton species indeterminate	
ADDITIONAL SPECIES			
1.		**11.**	
2.		**12.**	
3.		**13.**	
4.		**14.**	
5.		**15.**	
6.		**16.**	
7.		**17.**	
8.		**18.**	
9.		**19.**	
10.		**20.**	

COMMENTS

Data archived by: ________ **Date of archive:** __/__/__

Is this an audit survey? Yes ☐ No ☐

Quality Assurance Audit Protocol (tick as appropriate): Level 1 ☐ Level 2 ☐ None ☐

Table A1 List of Mean Trophic Rank scoring taxa, with recent synonyms

Notes:

1. Names of 'highlighted species' are indicated by ➢ and are given in bold type.
2. Recent synonyms (Syn.) are listed. These are based on Stace (1991) and in addition: Kent (1992) for angiosperms, Smith (1990) for bryophytes and Jermy et al (1982) for sedges. Authorities are included only where omission would cause confusion.
3. 'Include hybrids' denotes that hybrids of the species indicated should be included in the taxon for scoring purposes.
4. Up to and including 1996, *Stigeoclonium tenue* was assigned an STR of 1 (Holmes 1996). This species has subsequently been removed from the list of scoring taxa (Dawson et al 1999b).

ALGAE	SYNONYM(S), COMMENTS, HYBRIDS	STR
Batrachospermum species		6
Hildenbrandia rivularis		6
Lemanea fluviatillis		7
➢ **Vaucheria** species		1
➢ **Enteromorpha species**		1
➢ **Hydrodictyon reticulatum**		3
➢ **Cladophora** aggregate	Includes all species except *C. aegagropila* and *C. rhizoclonium* (Synonyms for *C. aegagropila: C. sauteri, Aegagropila sauteri*)	1

LIVERWORTS		
➢ **Chiloscyphus polyanthos**		8
Jungermania atrovirens	Syn. *Solenostoma triste*	8
➢ **Marsupella emarginata**		10
➢ **Nardia compressa**	Syn. *Alicularia compressa*	10
Pellia endiviifolia	Syn. *P. fabbroniana*	6
Pellia epiphylla		7
➢ **Scapania undulata**		9

MOSSES		
Amblystegium fluviatile	Syn. *Hygroamblestegium fluviatile*	5
➢ **Amblystegium riparium**	Syn. *Hypnum riparium* or *Leptodictyum riparium*	1
Blindia acuta		10
Brachythecium plumosum		9
Brachythecium rivulare		8
Brachythecium rutabulum		3
Bryum pseudotriquetrum		9
Calliergon cuspidatum	Syn. *Acrocladium cuspidatum* or *Calliergonella cuspidatum* or *Hypnum cuspidatum*	8
Cinclidotus fontinaloides		5
Dichodontium flavescens		9
Dichodontium pellucidum		9
	continued....	

MOSSES (continued....)	SYNONYM(S), COMMENTS, HYBRIDS	STR
Dicranella palustris	Syn. *D. squarrosa* or *Anisothecium palustris*	10
➤ **Fontinalis antipyretica**		5
➤ **Fontinalis squamosa**		8
➤ **Hygrohypnum ochraceum**	Syn. *Hypnum ochraceum*	9
➤ **Hygrohypnum luridum**	Syn. *Hypnum palustre*	9
➤ **Hyocomium armoricum**	Syn. *H. flagellare*	10
Philonotis fontana		9
Polytrichum commune		10
Racomitrium aciculare		10
➤ **Rhynchostegium riparioides**	Syn. *Eurynchium riparioides*	5
➤ **Sphagnum species**		10
Thamnobryum alopecurum		7

FERNS & HORSETAILS		
➤ **Azolla filiculoides**		3
Equisetum fluviatile	Include hybrids	5
Equisetum palustre	Include hybrids	5

DICOTYLEDONS		
➤ **Apium inundatum**	Syn. *Sison inundatum*	9
➤ **Apium nodiflorum**	Syn. *Sium nodiflorum.* Include hybrids.	4
➤ **Berula erecta**	Syn. *Sium erecta* or *Siella erecta*	5
Callitriche species indeterminate		non scoring
➤ **Callitriche hamulata**	Syn. *C. intermedia ssp hamulata*	9
➤ **Callitriche obtusangula**		5
➤ **Ceratophyllum demersum**		2
➤ **Hippuris vulgaris**		4
➤ **Littorella uniflora**		8
Lotus pedunculatus	Syn. *L. uliginosus*	8
➤ **Menyanthes trifoliata**		9
Montia fontana		8
➤ **Myriophyllum alterniflorum**		8
➤ **Myriophyllum spicatum**		3
➤ **Myriophyllum species**	Indeterminate species, but NOT *M. aquaticum (M. brasiliense)*	6
➤ **Nuphar lutea**	Include hybrids	3
➤ **Nymphaea alba**		6
➤ **Nymphoides peltata**	Syn. *Limnanthemum*	2
Oenanthe crocata	Syn. *O. phellandrium*	7
➤ **Oenanthe fluviatilis**		5
Persicaria amphibia	Syn. *Polygonum amphibium*	4
	continued....	

DICOTYLEDONS (continued....)	SYNONYM(S), COMMENTS, HYBRIDS	STR
Potentilla erecta	Syn. *Tomentilla erecta* or *Comarum erecta*. Include hybrids.	9
➤ **Ranunculus aquatilis**	Include hybrids	5
➤ **Ranunculus circinatus**		4
Ranunculus flammula		7
➤ **Ranunculus fluitans**	Include hybrids	7
Ranunculus hederaceus		6
Ranunculus omiophyllus	Syn. *R. lenormandii*. Include hybrids	8
➤ **Ranunculus peltatus**	Syn. *R. aquatilis ssp. peltatus*. Include hybrids	4
➤ **Ranunculus penicillatus**	Use this category for historical data when the subspecies/variety has not been recorded. Include hybrids.	5
➤ **Ranunculus penicillatus subspecies penicillatus**	Include hybrids	6
➤ **Ranunculus penicillatus subspecies pseudofluitans**	Include hybrids. Synonyms: *R. pseudofluitans* *R. aquatilis v.pseudofluitans* *R. peltatus v. pseudofluitans*	5
- **variety calcareus**	*R. penicillatus v. calcareus*	5
- **variety vertumnus**	*R. penicillatus v. vertumnus*	5
Ranunculus sceleratus		2
➤ **Ranunculus trichophyllus**	Include hybrids	6
➤ **Ranunculus species indeterminate**	Batrachium or aquatic species only. Include hybrids.	6
Rorippa amphibia	Syn. *Nasturtium amphibia* or *Sisymbrium amphibia*. Include hybrids.	3
➤ **Rorippa nasturtium-aquaticum**	Syn. *Nasturtium officinale* or *Sisymbrium nasturtium-aquaticum*	5
Rumex hydrolapathum	Include hybrids	3
➤ **Veronica anagallis-aquatica**	Include hybrids	4
➤ **Veronica catenata**	Syn. *V. aquatica*	5
➤ **Veronica anagallis-aquatica / catenata indeterminate**	Hybrids of *V. anagallis-aquatica* and *V. catenata*, or indeterminate forms of these species	4
Veronica scutellata		7
Viola palustris		9

MONOCOTYLEDONS		
Acorus calamus		2
Alisma plantago-aquatica	Include hybrids	3
Alisma lanceolatum		3
Bolboschoenus maritimus	Syn. *Scirpus maritimus* or *Schoenoplectus maritimus*	3
➤ **Butomus umbellatus**		5
Carex acuta	Syn. *C. gracilis* Curtis. Include hybrids.	5
Carex acutiformis	Include hybrids	3
Carex riparia	Include hybrids	4
	continued....	

MONOCOTYLEDONS (continued...)	SYNONYM(S), COMMENTS, HYBRIDS	STR
Carex rostrata	Syn. *C. ampullacea*. Include hybrids.	7
Carex vesicaria	Syn. *C. inflata*. Include hybrids.	6
Catabrosa aquatica	Syn. *Aira aquatica*	5
Eleocharis palustris	Syn. *Scirpus palustris*. Include hybrids.	6
➤ **Eleogiton fluitans**	Syn. *Scirpus fluitans* or *Isolepis fluitans*	10
➤ **Elodea canadensis**	Syn. *Anacharis canadensis*	5
➤ **Elodea nuttallii**	Syn. *Anacharis nuttallii* or *Hydrilla nuttallii*	3
Glyceria maxima	Note that *G. notata* (Syn. *G. plicata*), *G. fluitans*, *G. declinata* are non-scoring.	3
➤ **Groenlandia densa**	Syn. *Potamogeton densus*	3
➤ **Hydrocharis morsus-ranae**		6
Iris pseudacorus		5
➤ **Juncus bulbosus**		10
➤ **Lemna gibba**		2
➤ **Lemna minor**		4
➤ **Lemna minuta**	Syn. *L. minuscula*	3
➤ **Lemna trisulca**		4
Phragmites australis	Syn. *P. communis*	4
Potamogeton species indeterminate		non scoring
➤ **Potamogeton alpinus**	Include hybrids	7
➤ **Potamogeton berchtoldii**	Include hybrids	4
➤ **Potamogeton crispus**		3
➤ **Potamogeton freisii**	Include hybrids	3
➤ **Potamogeton gramineus**	Include hybrids	7
➤ **Potamogeton lucens**	Include hybrids	3
➤ **Potamogeton natans**	Include hybrids	5
➤ **Potamogeton obtusifolius**		5
➤ **Potamogeton pectinatus**	Include 'forms'	1
➤ **Potamogeton perfoliatus**		4
➤ **Potamogeton polygonifolius**	Include hybrids	10
➤ **Potamogeton praelongus**	Include hybrids	6
➤ **Potamogeton pusillus**	Syn. *P. panormitanus*. Include hybrids.	4
➤ **Potamogeton trichoides**	Include hybrids	2
➤ **Sagittaria sagittifolia**		3
➤ **Schoenoplectus lacustris**	Syn. *Scirpus lacustris*. Include hybrids.	3
➤ **Sparganium emersum**	Syn. *S. simplex*. Include hybrids	3
➤ **Sparganium erectum**	Various subspecies	3
➤ **Spirodela polyrhiza**	Syn. *Lemna polyrhiza*	2
Typha latifolia	Include hybrids	2
Typha angustifolia		2
➤ **Zannichellia palustris**		2

STANDARD SKETCH MAP SHEET (MACROPHYTE SURVEY, 100m)

River name ______________ Site name ______________ Date __/__/__

NGR top ______________ NGR bottom ______________

100 m ______________________________

LEFT BANK RIGHT BANK

DIRECTION OF FLOW ↑

90 m ______________________________

80 m ______________________________

70 m ______________________________

60 m ______________________________

50 m ______________________________

40 m ______________________________

30 m ______________________________

20 m ______________________________

10 m ______________________________

0 m ______________________________

Main features to mark on sketch map:-

River channel
Width of channel
Relocation features
Shading position and type
Grid north (found from OS map)
Dominant macrophyte stands
Extent of riverbanks and adjacent land use
Depth of water

Label clearly.

STANDARD SKETCH MAP SHEET (MACROPHYTE SURVEY, 500m)

River name ____________ Site name ____________ Date __/__/__

NGR top ____________ NGR bottom ____________

500 m ____________

LEFT BANK RIGHT BANK

DIRECTION

OF FLOW ↑

450 m ____________

400 m ____________

350 m ____________

300 m ____________

250 m ____________

200 m ____________

150 m ____________

100 m ____________

50 m ____________

0 m ____________

Main features to mark on sketch map:-

River channel
Width of channel
Relocation features
Shading position and type
Grid north (found from OS map)
Dominant macrophyte stands
Extent of riverbanks and adjacent land use
Depth of water

Label clearly.

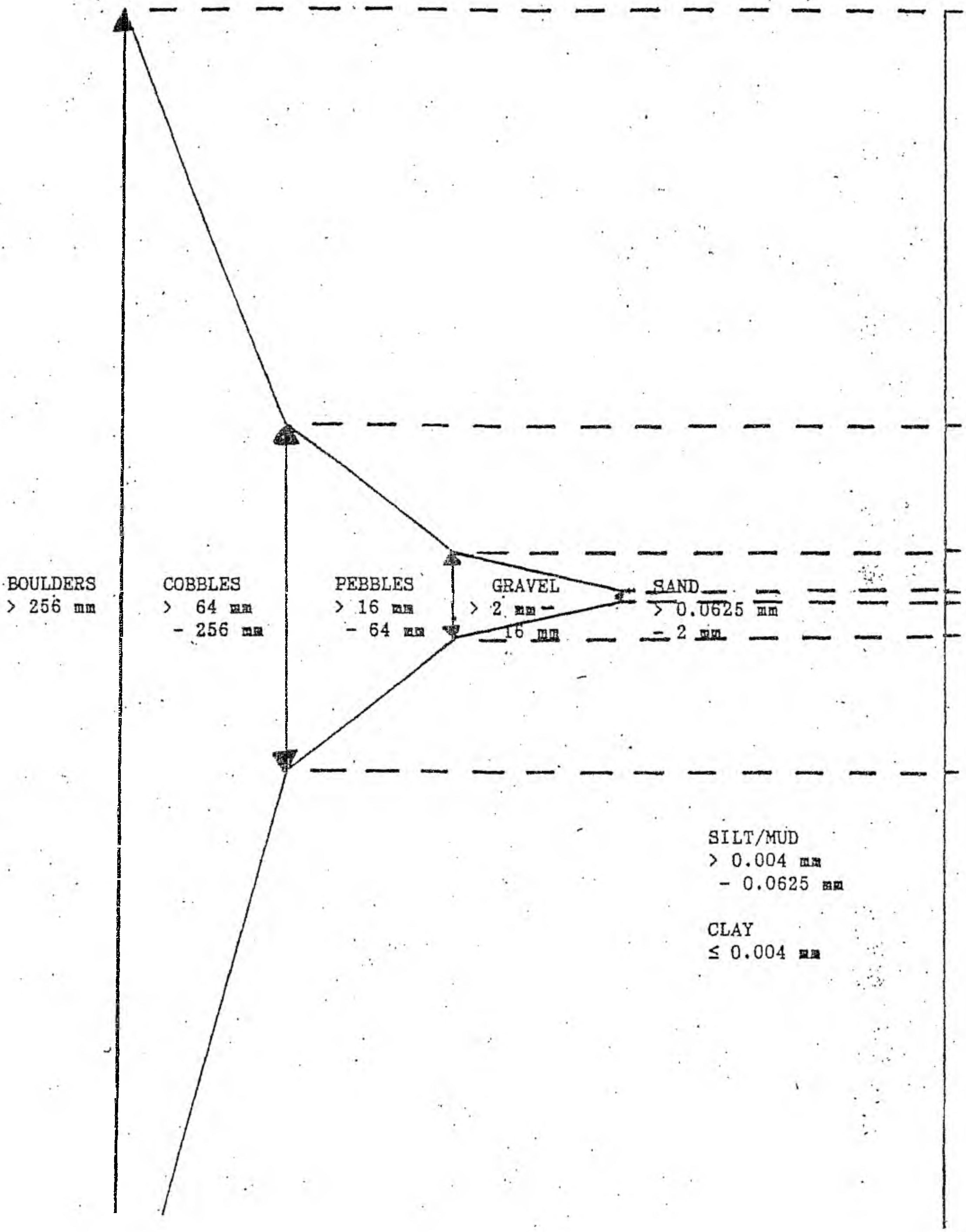
Table A2 Cover (m^2) for 100m Sections

		AVERAGE RIVER WIDTH (M)														
Cover Value	Equivalent %	1	2	3	4	5	6	7	8	9	10	11	12	15	20	25
1	<0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.5	2	2.5
2	0.1 - 1	0.1 - 1	0.2 - 2	0.3 - 3	0.4 - 4	0.5 - 5	0.6 - 6	0.7 - 7	0.8 - 8	0.9 - 9	1 - 10	1.1 - 11	1.2 - 12	1.5 - 15	2 - 20	2.5 - 25
3	1 - 2.5	1 - 2.5	2 - 5	3 - 7.5	4 - 10	5 - 12.5	6 - 15	7 - 17.5	8 - 20	9 - 22.5	10 - 25	11 - 27.5	12 - 30	15 - 37.5	20 - 50	25 - 62.5
4	2.5 - 5	2.5 - 5	5 - 10	7.5 - 15	10 - 20	12.5 - 25	15 - 30	17.5 - 35	20 - 40	22.5 - 45	25 - 50	27.5 - 55	30 - 60	37.5 - 75	50 - 100	62.5 - 125
5	5 - 10	5 - 10	10 - 20	15 - 30	20 - 40	25 - 50	30 - 60	35 - 70	40 - 80	45 - 90	50 - 100	55 - 110	60 - 120	75 - 150	100 - 200	125 - 250
6	10 - 25	10 - 25	20 - 50	30 - 75	40 - 100	50 - 125	60 - 150	70 - 175	80 - 200	90 - 225	100 - 250	110 - 275	120 - 300	150 - 375	200 - 500	250 - 625
7	25 - 50	25 - 50	50 - 100	75 - 150	100 - 200	125 - 250	150 - 300	175 - 350	200 - 400	225 - 450	250 - 500	275 - 550	300 - 600	375 - 750	500 - 100	625 - 1250
8	50 - 75	50 - 75	100 - 150	150 - 225	200 - 300	250 - 375	300 - 450	350 - 525	400 - 600	450 - 675	500 - 750	550 - 825	600 - 900	750 - 1125	1000 - 1500	1250 - 1675
9	> 75	>75	>150	>225	>300	>375	>450	>525	>600	>675	>750	>825	>900	>1125	>1500	>1675

Note:
$0.1\ m^2 = 32cm \times 32cm$
$0.2\ m^2 = 45cm \times 45cm$
$0.5\ m^2 = 71cm \times 71cm$
$0.8\ m^2 = 90cm \times 90cm$
$2\ m^2 \approx 1.4m \times 1.4m$
$5\ m^2 \approx 2.2m \times 2.2m$
$9\ m^2 = 3m \times 3m$
$20\ m^2 \approx 4.5m \times 4.5m$
$30\ m^2 \approx 5.5m \times 5.5m$
$50\ m^2 \approx 7m \times 7m$
$75\ m^2 \approx 8.5m \times 8.5m$
$90\ m^2 \approx 9.5m \times 9.5m$

SUBSTRATE REFERENCE SHEET

Substrate categories and size ranges are marked. Use this sheet to determine the category of substrates in the field.

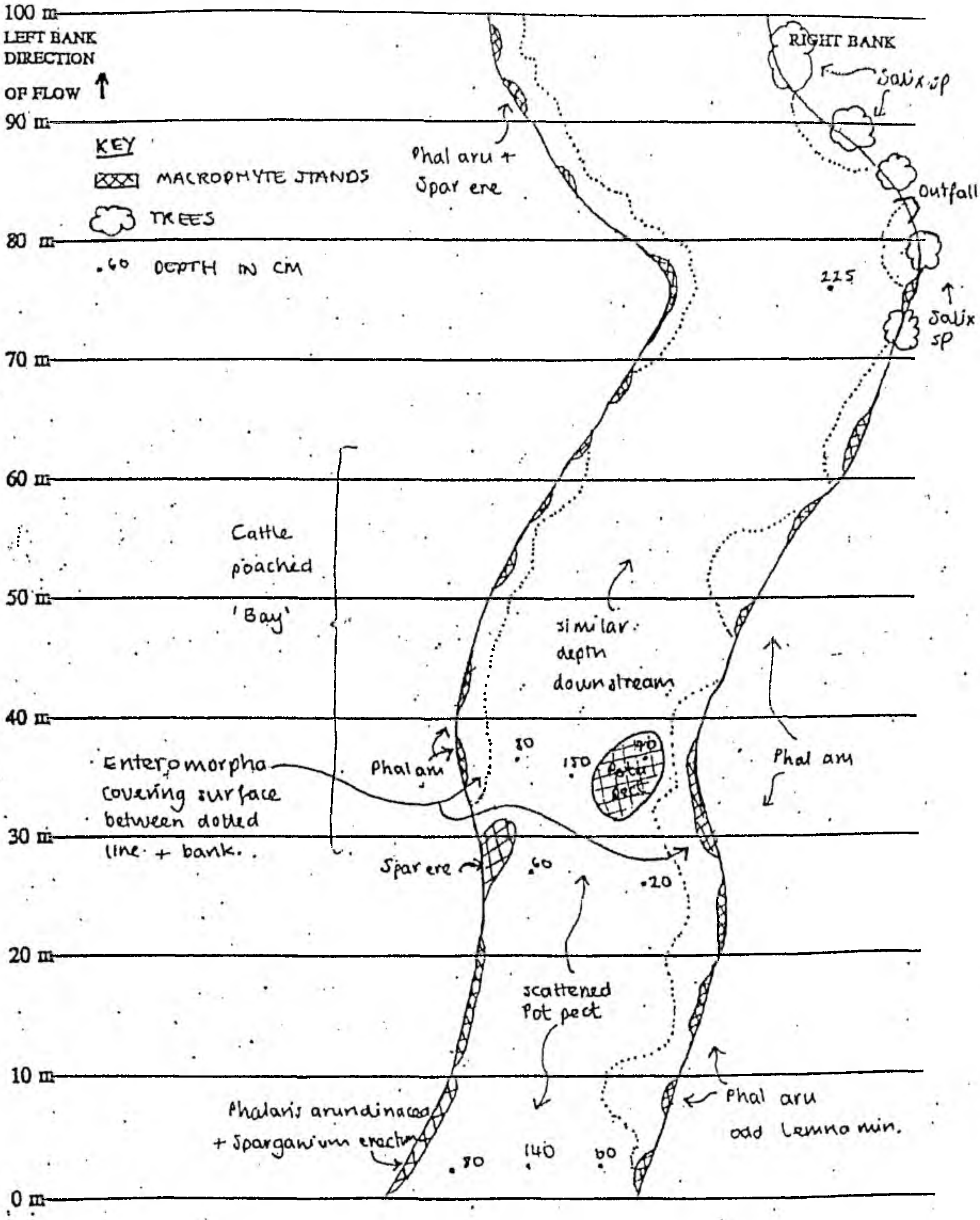


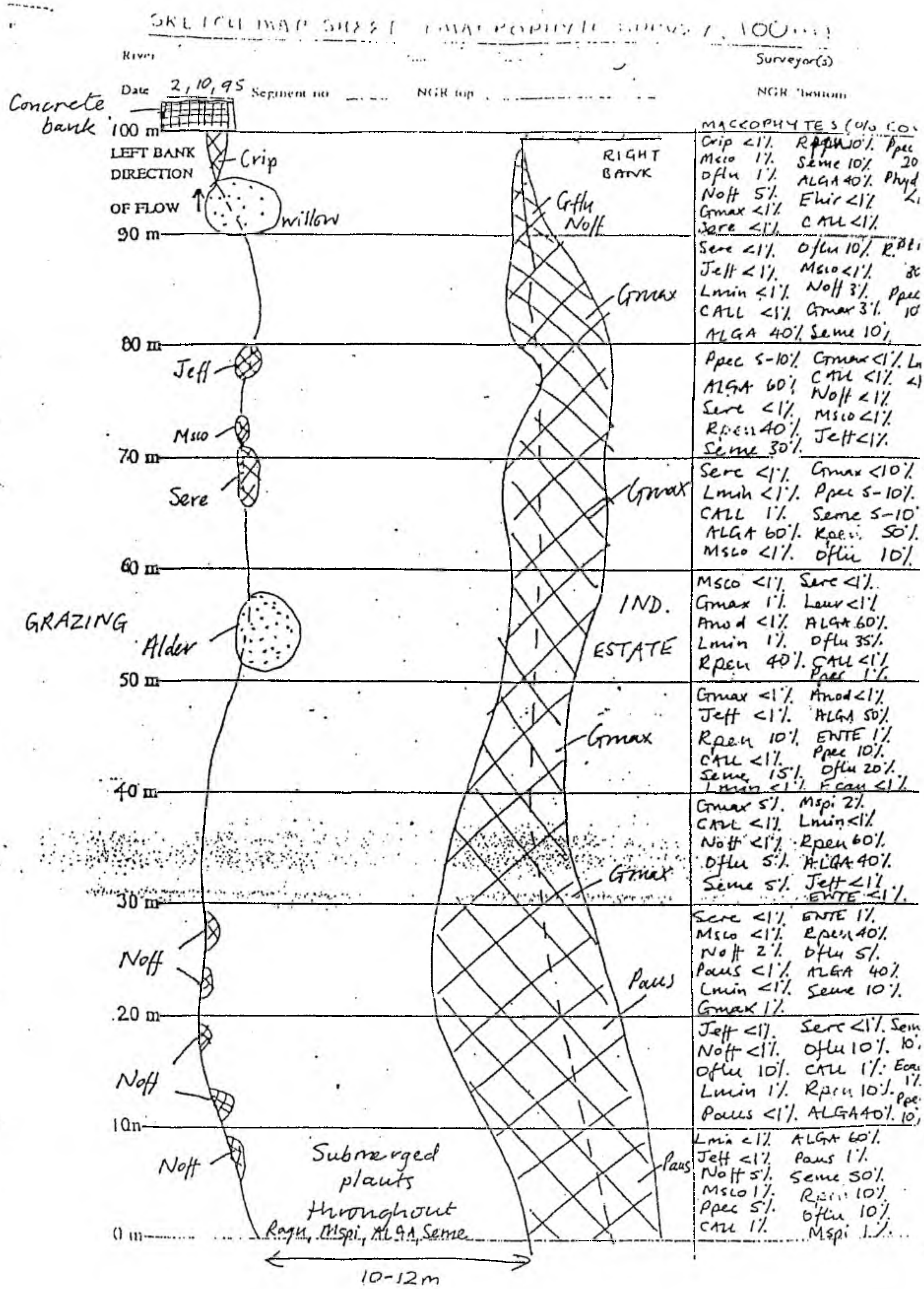
Appendix 6 Example sketch maps

STANDARD SKETCH MAP SHEET (MACROPHYTE SURVEY, 100 m)

River ______ Site ______ Surveyor(s) ______

Date ______ Segment no. ______ NGR top ______ NGR bottom ______

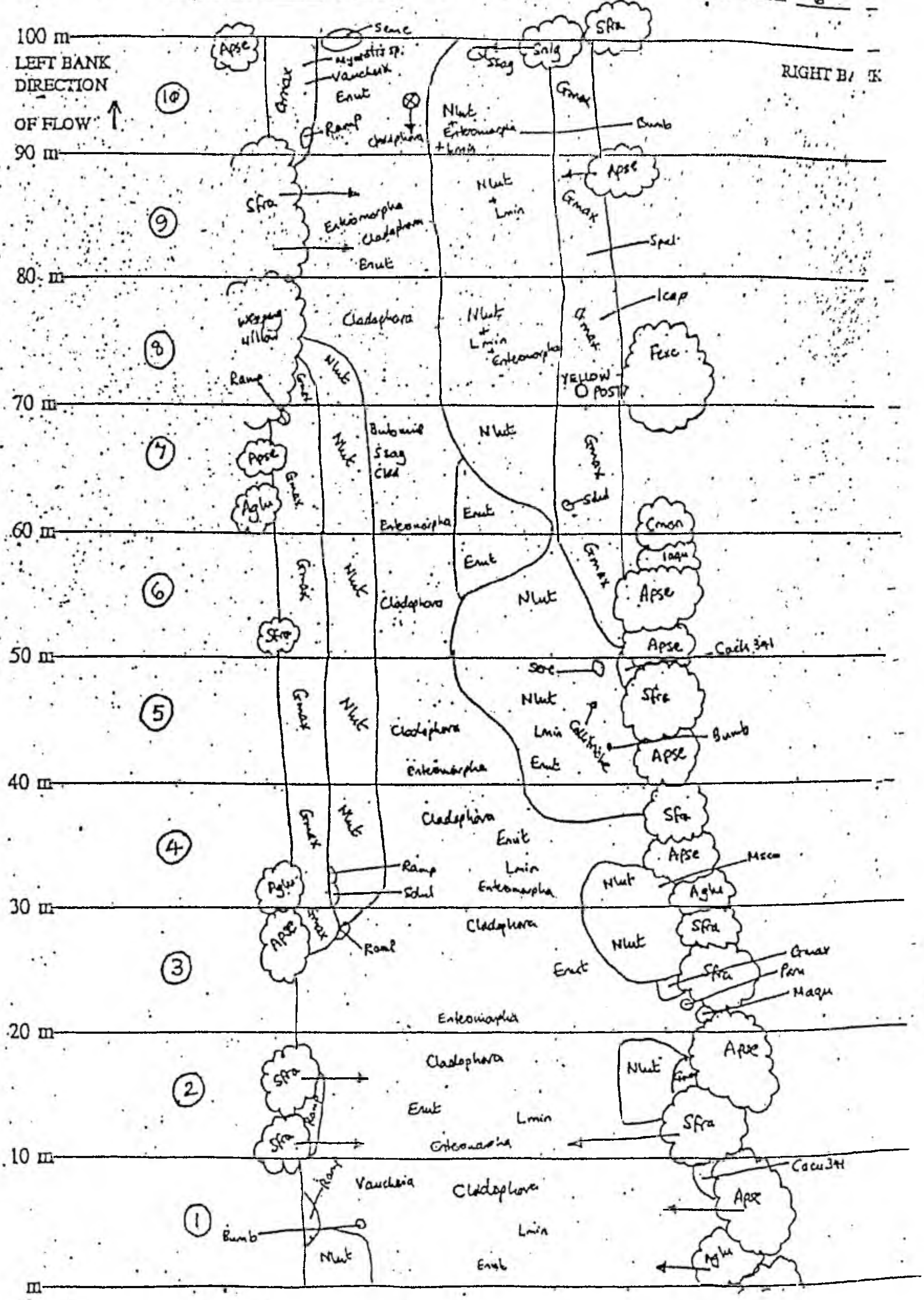



Surveyor(s)
Date 2/10/95
Segment no
NGR top
NGR bottom
Concrete bank
100 m
LEFT BANK
DIRECTION OF FLOW
RIGHT BANK
Crip
willow
Gflu
Noff
90 m
Gmax
80 m
Jeff
Msco
70 m
Sere
Gmax
60 m
GRAZING
Alder
IND. ESTATE
50 m
Gmax
40 m
Gmax
30 m
Noff
Paus
20 m
Noff
10m
Noff
Paus
Submerged plants throughout
Ragu, Mspi, ALGA, Seme
0 m
10-12m
Crip <1% Msco 1% Oflu 1% Noff 5% Gmax <1% Sere 10% ALGA 40% Ehir <1% CALL <1%
Sere <1% Jeff <1% Lmin <1% CALL <1% ALGA 40% Oflu 10% Msco <1% Noff 3% Gmax 3% Seme 10%
Ppec 5-10% ALGA 60% Sere <1% Rpen 40% Seme 30% Gmax <1% CALL <1% Noff <1% Msco <1% Jeff <1%
Sere <1% Lmin <1% CALL 1% ALGA 60% Msco <1% Gmax <10% Ppec 5-10% Seme 5-10 Rpen 50% Oflu 10%
Msco <1% Gmax 1% Anod <1% Lmin 1% Rpen 40% Sere <1% Leur <1% ALGA 60% Oflu 35% CALL <1% Ppec 1%
Gmax <1% Jeff <1% Rpen 10% CALL <1% Seme 15% Lmin <1% Anod <1% ALGA 50% ENTE 1% Ppec 10% Oflu 20% Fcan <1%
Gmax 5% CALL <1% Noff <1% Oflu 5% Seme 5% Mspi 2% Lmin <1% Rpen 60% ALGA 40% Jeff <1% ENTE <1%
Sere <1% Msco <1% Noff 2% Paus <1% Lmin <1% Gmax 1% ENTE 1% Rpen 40% Oflu 5% ALGA 40% Seme 10%
Jeff <1% Noff <1% Oflu 10% Lmin 1% Paus <1% Sere <1% Oflu 10% CALL 1% Rpen 10% ALGA 40%
Lmin <1% Jeff <1% Noff 5% Msco 1% Ppec 5% CALL 1% ALGA 60% Paus 1% Seme 50% Rpen 10% Oflu 10% Mspi 1%

...SURVEY, 100 m)

RIVER ____________ Site 100 m u/s ____________ Surveyor(s) ____________

Date 13/7/95 Segment no. ______ NGR top SP 3 6 NGR bottom SP3 6



Appendix 7 Summary of methodology, definitions and equipment checklist

MTR SURVEY: SUMMARY OF METHODOLOGY

Before you go out

Ensure that you have all the equipment you need and are familiar with appropriate health and safety guidance.

Prior to commencing the survey

1. Confirm that the site is suitable for a MTR survey. Think again if:
   - the suffixes of confidence for the survey and comparability are C and/or III
   - there has been a recent temporal perturbation (eg spate or weed-cutting)
   - flows are high and/or the water is turbid
   - there is heavy/steady rain and/or windy conditions
   - an alternative method is more appropriate.

2. Select/locate the survey length.
   - Use the sketch/location map if the survey length has been surveyed before.
   - If this is a new site, select the most appropriate survey length, giving consideration to the factors influencing the MTR.
   - The survey length is 100m long: measure (or pace) out and mark. For its width, see the definition of the 'channel'.

   Exceptions to surveying the full survey-length are:
   - if the river is very wide and/or deep and it is impractical to survey the full width, then a 5m wide (minimum) strip down one side of the channel may be surveyed instead (downstream length to be on the discharge side)
   - if an effluent tracks along one bank for at least 500m, then a 5m wide (minimum) strip down that side of the channel can be surveyed, provided that a full-width survey is undertaken first;
   - if a mature island is located within the survey length when assessing the impact of a discharge, then only the side on which the discharge enters should be surveyed;
   - if there is a deep or rapid area(s), not exceeding 20% of an otherwise wadeable site, which is impractical to survey using a boat and a camera/bucket, then this may be left as a 'black hole' (mark clearly on the map and discount from all plant cover and physical attribute estimates except width).
   - if it is impossible to find two comparable 100m sites near to the discharge being assessed, then 50m reaches of similar character may be surveyed, provided the river is at least 10m wide.

3. Complete the site and survey details on the standard field recording sheets.

The Survey

4. Aim to traverse the channel 4 times in every 10m length of river, either by wading or by boat as appropriate. In narrow, non-wadeable sites, the survey can be undertaken from the bank.

5. Assess and record all macrophytes present within the survey length, and their individual percentage cover class (SCV), using the standard field recording sheet.
   - This includes: all macrophytes likely to be submerged for more than 85% of the time; both scoring and non-scoring plants.
   - Do not record macrophytes overhanging but not rooted in the channel area, nor detached macrophyte material except for floating species. Include macrophytes on artificial structures only if a similar structure is present at both sites being compared.
   - Use a glass-bottomed bucket or underwater camera to improve visibility, where appropriate.
   - Take particular care to look out for small patches of species, which may otherwise be missed.
   - Only use grapnels to retrieve specimens for identification.

- If you are unsure about the identification of a species, take a representative sample back to the laboratory to confirm identification: this is especially important for bryophytes, filamentous algae, *Callitriche* and *Ranunculus* species. Use of *Ranunculus species indeterminate #1* and *#2* is allowed provided identification notes on made under 'Comments' and a sample retained in the herbarium.
- Collect herbarium material if required (herbarium should include all regularly encountered species).
- Use one of the recommended methods to estimate the percentage cover of individual species. The standard abundance scale for 100m surveys is the 9-point Scale C.

6. Estimate the overall percentage cover of macrophytes in the survey length. Use as a double-check on the total of the percentage covers of individual species, but remember that the overall cover can be less than the total of the individual percentage covers if there are layers of macrophytes overlying each other.

7. Assign a measure of confidence in the survey (A, B or C: see definition).

8. Assess and record the physical character of the survey length, using the standard field recording sheet.
   - Record either actual percentages and/or categories/classes in a manner which allows comparison with previous surveys. Record percentages to integer values (the nearest percentage point).
   - If a feature is absent, record this as 0% (category 0): do not leave data entry spaces/boxes unfilled.
   - If a feature is present at less than 0.5%, then ignore unless that particular habitat type contains the only occurrence of a scoring species, in which case note it under 'Comments' and mark its position on the sketch map.
   - 'Width' means the channel width for which macrophyte species have been recorded. Use one of the recommended methods for measuring or estimating width.
   - The shading for each bank is recorded separately. The percentage recorded for shading from each bank should relate to the whole channel width, not just half the width. The percentage of the channel affected by shading is recorded, NOT the length of bank on which vegetation causing shade stands. The percentage of the channel recorded as shaded is that shaded when the sun is directly overhead - midday.

9. Draw a sketch map of the survey length, using the standard field recording sheet.
   - The purpose of this map is to enable a future surveyor to re-locate the survey length.
   - If starting from the upstream end of the survey length, the left side of the paper corresponds to the left bank. If starting from the downstream end, turn the map upside down.
   - Use the list on the back of the recording sheet as a guide as to what to record.
   - Relocation features include any permanent features such as fences, hedges, walls, bridges etc. It may also be useful to mark (on a separate location map if necessary), the position of suitable parking and access, as this may also help re-location.

10. Take a photograph of the survey length to record its general character.
    - The use of a polarising filter to reduce surface reflection is recommended.
    - Write the date and an identifying code or site name and river name on a small blackboard or wipe-clean board and place this in the photograph. Record the identifying code on the record sheet.

11. If the results from the survey are to be compared with those from another site, assign a measure of confidence for comparability of the survey lengths (I, II or III: see definition).

12. Before you leave the site, check that all the data entry boxes/spaces on the field recording sheets have been completed, and that you have drawn a sketch map and taken a photograph.

Back at the Laboratory
Remember to keep representative specimens in a herbarium or 'voucher collection', for future reference or confirmation.

MTR SURVEY: DEFINITIONS

Channel

All macrophytes seen submerged or partly submerged in the river, at low flow levels, within the survey length are recorded. These are considered to be 'river' plants. At the sides of the river all macrophytes attached or rooted on parts of the substrata which are likely to be submerged for more than 85% of the time are included.

Species Cover Value (SCV)

The alternative Species Covers Value class scales are:-

SCALE A (for 500m survey)		SCALE C (for 100m survey length)	
A1	<0.1%	C1	<0.1%
A2	0.1-1%	C2	0.1-1%
A3	1-5%	C3	1-2.5%
A4	5-10%	C4	2.5-5%
A5	>10%	C5	5-10%
		C6	10-25%
		C7	25-50%
		C8	50-75%
		C9	>75%

Substrata Classes

Bedrock	-	exposure of underlying rock not covered by alluvial deposits
Boulders/Cobbles	-	> 64 mm; half-fist size or larger
Pebbles/Gravel	-	> 2–64 mm; half-fist to coffee granule size
Sand	-	> 0.0625–2 mm; smaller than coffee granules and unlike silt/clay, abrasive to the hands
Silt/Clay	-	< 0.0625; has a soft texture
Peat	-	dead vegetation undergoing bacterial decay in stagnant deoxygenated water. Strictly pure peat, not fine peaty deposits over more substantial substrate.

Habitats (NB these definitions are NOT as used for RHS)

Pool	-	Either a discrete area of slow flowing water, usually relatively deeper than surrounding water, or between faster flowing stretches, as in a sequence of riffle-pool- riffle. Pools are deep and often turbulent, and scoured during spate flows.
Riffle	-	Fast flowing, shallow water whose surface is distinctly disturbed. This does not include water whose surface is disturbed by macrophyte growth only.
Run	-	Fast or moderate flowing, often deeper water whose surface is rarely broken or disturbed except for occasional swirls and eddies.
Slack	-	Deep, slow flowing water, uniform in character.

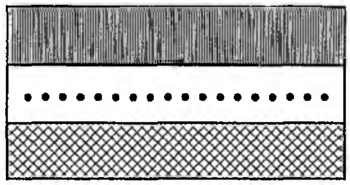
Shading Categories

None	-	no shading
Broken	-	some direct sunlight hits the water surface in the shade affected area when the sun is directly overhead.
Dense	-	5% or less of the shade-affected area receives direct sunlight when the sun is directly overhead.

On the sketch map - Broken shade should be indicated by:

Dense shade should be indicated by:

Macrophyte stands should be indicated by:



Water Clarity

Clear - Channel substrate is clearly visible at all depths, as are macrophyte species.

Cloudy - Slightly discoloured with a moderate suspended solids load and partially reduced light penetration. All clumps of macrophyte species can be located on the substrate of the river channel but the view of them is partially distorted. A small piece/single shoot of a macrophyte species may be missed.

Turbid - Strongly discoloured, carrying a heavy suspended solids load and greatly restricted light penetration. The channel bed is obscured and submerged macrophyte species are indistinguishable from substrate and water. This will lead to a reduction in accuracy and efficiency of the method.

Bed Stability

Solid/firmly bedded - eg bedrock/compacted clay, increased flow has little effect

Stable - eg boulders/pebbles/gravel, unlikely to be significantly altered by increased flows

Unstable - eg gravel/sand/silt/mud, likely to be dislodged by increased flows

Soft/sinking - eg deep silt/mud, making channel unwadeable. Bank stick penetrates easily into substrate.

Suffix of Confidence in the Survey

Assess how accurately you feel the results reflect the prevailing situation at the site. For example, the survey may have been hampered and perhaps rendered meaningless by:

- temporal perturbations such as recent river management (dredging, weed cutting, herbicide application or disturbance due to flood defence works such as bank reinforcements) or extreme flooding events, which may have influenced the macrophyte community; and/or
- survey conditions which reduce the accuracy of the survey, *e.g.* poor survey conditions (turbidity, high discharge due to recent rain or very wet or windy conditions) or excessive blanketing algae or floating vegetation growth obscuring the view or smothering other vegetation.

Note that confidence in the results of a survey may be restricted by either one or both of the above factors.

Assign a score according to the degree to which such events may have distorted the survey findings:

A - data not affected or any effect limited to less than 25% of the site

B - the accuracy of records in 25–50% of the site influenced to a considerable degree

C - the accuracy of records in >50% of the site influenced to a considerable degree.

Suffix of Confidence in the Comparability of Survey Lengths

The factors under consideration for comparison are Width, Depth, Substrata, Habitats, Shading, Water Clarity and Bed Stability. For each pair of survey lengths, assign one of the following categories:

I - 5 or more of these characteristics are similar for more than 75% of each site.

II - 3 or 4 of these categories are similar for more than 75% of each site.

III - 2 or less of these categories are similar for more than 75% of each site.

MTR: EQUIPMENT CHECKLIST

- Safety equipment - refer to safety manuals and advice available from your manager or safety advisor.
- Maps - Ordnance Survey 1:50 000
- Location and/or sketch map to enable accurate location of the survey length (if surveyed before)
- Standard record sheets + sketch map sheet (on waterproof paper if necessary)
- Summary of the MTR methodology and definitions reference sheets (optional, preferably laminated Appendix 5)
- Substrate reference and % cover reference sheets (optional)
- Pencil and pen
- Clipboard with waterproof shield/cover or a large clear plastic bag (to protect record sheet and make writing possible in damp conditions).
- Grapnel with depth markings on the rope
- Bank stick with depth markings
- Plastic bags, labels and tubes for small specimens
- Tape measure or measuring rope, stakes and mallet (to mark start and end of survey length)
- Identification and field guides
- Camera with a polarising lens and 200 ISO daylight film speed.
- Hand lens (x10)
- Blackboard & chalk or wipe-clean board, non permanent pen and cloth (small, to include site details in the photographs)
- Underwater viewing aid (eg glass-bottom bucket or underwater TV camera)
- Polarising sunglasses (optional)
- Optical range finder (optional)
- Boat and additional safety equipment as required.
- Copies of previous survey sheet(s) for site(s) to be surveyed (optional).

INDEX

This index is intended to help the user find key sections of the manual, and is not intended to be an exhaustive index of subjects covered.

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